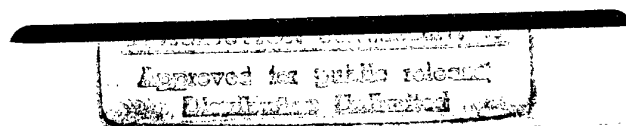


AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE, 92200 NEUILLY-SUR-SEINE, FRANCE



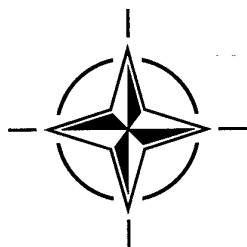
AGARD ADVISORY REPORT 352

Medical Screening of Subjects for Acceleration and Positive Pressure Breathing

(la Surveillance médicale des sujets relative aux accélérations
et à la surpression ventilatoire)

*Papers and discussions from the Aerospace Medical Panel Workshop held in Prague,
Czech Republic, May 1996.*

19970728 024



NORTH ATLANTIC TREATY ORGANIZATION

Published July 1997

Distribution and Availability on Back Cover

7 RUE ANCELLE, 92200 NEUILLY-SUR-SEINE, FRANCE

North Atlantic Treaty Organization
Organisation du Traité de l'Atlantique Nord

The Mission of AGARD

According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Exchange of scientific and technical information;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The content of this publication has been reproduced
directly from material supplied by AGARD or the authors.

Published July 1997

Copyright © AGARD 1997
All Rights Reserved

ISBN 92-836-0045-2



*Printed by Canada Communication Group Inc.
(A St. Joseph Corporation Company)
45 Sacré-Cœur Blvd., Hull (Québec), Canada K1A 0S7*

Medical Screening of Subjects for Acceleration and Positive Pressure Breathing

(AGARD AR-352)

Executive Summary

The Aerospace Medical Panel (AMP) of the Advisory Group for Aerospace Research and Development (AGARD) sponsored a Workshop to address questions related to the "Medical Surveillance of Subjects for Acceleration and Positive Pressure Breathing Experimentation". The concept underlying the Workshop was that occupational concerns related to acceleration and positive pressure breathing in NATO aircrew can be addressed by careful monitoring of subjects for research in these areas who are repeatedly exposed and are already carefully medically scrutinized. The objectives of the Workshop were to assemble medical monitors from the various NATO facilities conducting research in acceleration (G) and positive pressure breathing (PPB), in order to:

- a) identify areas of potential aeromedical occupational concern related to exposure to G and PPB;
- b) develop AGARD/AMP Consensus Guidelines for medical screening and monitoring of subjects for such research;
- c) create a registry of medical events in NATO centrifuges and a database to track such events;
- d) explore the feasibility of utilizing the power of the collective denominator of NATO/AMP through a Working Group to address the medical occupational concerns related to G and PPB exposures of military aircrew.

The objectives of the Workshop were met. All NATO countries with active research facilities in G and PPB were represented, with additional participation by representatives from Poland, Sweden and Japan, and observers from the Czech Republic. Consensus Guidelines for medical screening and surveillance of research subjects were developed and are included in this publication. In addition, a consensus recommendation was put forward to the AGARD Aerospace Medical Panel, to initiate a Working Group to pursue the important occupational questions related to exposure to acceleration and positive pressure breathing in NATO aircrew by pooling data from NATO subjects participating in such research.

La surveillance médicale des sujets relative aux accélérations et à la surpression ventilatoire

(AGARD AR-352)

Synthèse

Le Panel de médecine aérospatiale de l'AGARD (AMP) a organisé un atelier afin d'examiner un certain nombre de questions concernant le suivi médical d'individus pour l'expérimentation relative aux accélérations et à la surpression ventilatoire. Le concept qui sous-tendait l'atelier était que les préoccupations du corps médical concernant les accélérations subies par les équipages de l'OTAN et les techniques de surpression ventilatoire utilisées pour surmonter les problèmes engendrés peuvent être abordées par le suivi attentif, aux fins de la recherche, des individus qui sont exposés à de telles situations de façon répétitive et qui font déjà l'objet d'un suivi médical rigoureux.

Le groupe s'est fixé pour objectif de rassembler les responsables du suivi médical des différents organismes de l'OTAN qui réalisent des programmes de recherche dans le domaine des accélérations (G) et la surpression ventilatoire (PPB), afin de:

- a) identifier les questions aéromédicales préoccupantes concernant la recherche en accélérations et en surpression ventilatoire;
- b) élaborer des directives représentant une unité de vues AGARD/AMP sur la sélection et la surveillance des sujets pour de tels travaux de recherche;
- c) établir un registre OTAN des événements survenus lors des essais en centrifugeuse, ainsi qu'une base de données pour le suivi de tels événements;
- d) examiner la faisabilité de l'exploitation de la force que peut représenter le dénominateur commun OTAN/AMP, par le biais d'un groupe de travail afin de répondre aux préoccupations des médecins de l'air pour ce qui concerne l'exposition des équipages militaires aux G et au PPB.

Les objectifs de l'atelier ont été atteints. Tous les pays de l'OTAN dotés de moyens de recherche en G et PPB ont été représentés, avec en plus, une participation de représentants de la Pologne, de la Suède, du Japon, ainsi que des observateurs de la république tchèque. Des directives consensuelles sur la sélection et la surveillance des individus ont été établies et jointes au présent ouvrage. En outre, une recommandation commune a été faite au Panel de médecine aérospatiale de l'AGARD, à savoir que le Panel doit créer un groupe de travail pour étudier en détail les questions occupationnelles importantes relatives à l'exposition des équipages de l'OTAN aux accélérations et à la surpression ventilatoire, en s'appuyant sur la mise en commun des données obtenues des individus des forces de l'OTAN participant à de telles activités de recherche.

Contents

	Page
Executive Summary	iii
Synthèse	iv
Preface	vi
Aerospace Medical Panel Officers	vii
List of Workshop Participants	viii
Introduction by G.W. Gray, Workshop Chairman	1
REPORTS FROM PARTICIPATING COUNTRIES	
Canada by G.W. Gray and W.B. Bateman	6
France by J.M. Clère	9
Japan by S. Tachibana and S. Nishibe	12
Netherlands by N. Holewijn	13
Poland by W. Kowalski and M. Wojtkowiak	16
Sweden by P.G. Larsson	21
United Kingdom by N.D. Green	24
United States Air Force (formal report not submitted)	27
United States Navy by D. McGowan	28
Workshop Consensus Guidelines for Medical Screening of Subjects for Acceleration and PPB Research	30
Protocol for Reporting Centrifuge/PPB Incidents	33

Preface

What are the long-term medical complications, if any, of repetitive exposure to G-forces? This question is asked by current fighter pilots, retired pilots seeking compensation for various medical complaints, and by subjects for acceleration research and ethics committees reviewing the protocols for such research.

Does repetitive exposure to high G-forces affect the heart? the lungs? the axial spine? Does repetitive G-LOC cause any permanent functional neurologic sequelae?

So far, we have little more than case studies and anecdotal evidence to answer these questions. Pundits argue that if there were a significant problem, it would be obvious by now, but such an argument is transparent to any physician seriously concerned about occupational issues. The expansion of the G-envelope for next generation super-agile fighters with advanced life support equipment incorporating positive pressure breathing only heightens the concerns.

The recent AGARD Aerospace Medical Panel (AMP) Working Group 18 addressed the question of the possible cardiac effects of repetitive G-exposure in serving NATO pilots. This landmark study demonstrated that the AMP has the ability to carry out well-designed, controlled cross-sectional studies to provide answers to these questions.

This AMP Workshop invited the medical representatives from countries with centrifuge facilities to discuss the medical concerns about G exposure. Subjects for acceleration research form a highly medically screened cohort in whom medical concerns about G exposure can be addressed by pooling data.

Workshop participants presented the current procedures in place in their countries for screening acceleration subjects and presented anecdotal observations of medical complications related to G exposure.

The outcomes of the Workshop included:

- a consensus protocol to serve as a guideline for medical screening of subjects for acceleration research;
- a protocol for a database to track medical occurrences on NATO centrifuges
- a recommendation for a Working party to collate data in a study of NATO acceleration subjects to address the occupational concerns relevant to G.

Aerospace Medical Panel

Chairman: Dr P. VANDENBOSCH
Loriesstraat, 44
B-1500 Halle
Belgium

Deputy Chairman: LtCol A. ALNAES
Oslo Military Clinic
Oslo Mil/Akershus
N-0015 Oslo
Norway

PANEL EXECUTIVE

Mail from Europe & Canada:
Major R. POISSON, CF
AGARD/NATO
7, rue Ancelle
92200 Neuilly-sur-Seine, France

Mail from USA:
AGARD/NATO/AMP
PSC 116
APO AE 09777

Telephone: 33 (1) 55 61 22 60/62
Telefax: 33 (1) 55 61 22 99/98
Telex: 610176F

Workshop Participants

NAME	ADDRESS	TEL/FAX/E.MAIL	ROLE
Cdr Gary GRAY M.D., Ph.D.	DCIEM 1133 Sheppard Ave West North York, ON M3M 3B9 CANADA	Tel: 1 416 635 2015 Fax: 1 416 635 2104 Email: gary.gray@dciem.dnd.ca	Workshop Chairman Author Participant
LCdr Bill BATEMAN M.D.	DCIEM 1133 Sheppard Ave West North York, ON M3M 3B9 CANADA	Tel: 1 416 635 2159 Fax: 1 416 635 2104 Email: bill.bateman@dciem.dnd.ca	Author Participant
LtCol Petr DOSEL M.D.	Institute of Aviation Medicine Generala Píky 1 16060 Prague 6 CZECH REPUBLIC	Tel: 42 2 2020 8778	Observer
Col. Jiri SULC M.D., Ph.D.	Institute of Aviation Medicine Generala Píky 1 16060 Prague 6 CZECH REPUBLIC	Tel: 42 2 2021 2426	Observer
Col. Jean-Michel CLERE M.D., Ph.D.	CEV/LAMAS 91228 Brétigny/Orge FRANCE	Tel: 33 (0)1 6988 2392 Fax: 33 (0)1 6988 2725	Panel Member Author Participant
Col. Heiko WELSCH M.D.	Flugmedizinisches Institut der Luftwaffe Abt III Flugphysiologie Steinbornerstrasse 43 01936 Koenigsbrueck GERMANY	Tel: 49 35795 42522 Ext. 300 Fax: 49 35795 31982	Author Participant
LtCol. Shoichi TACHIBANA M.D.	JASDF Air Staff Office Defence Agency 9-7-45 Akasaka, Minato-Ku Tokyo 10 JAPAN	Tel: 03 3746 1496 Fax: same as phone	Author Participant
Drs Michael HOLEWIJN M.D.	NLRGC Netherlands Aeromedical Centre P O Box 22 3769 ZG Soesterberg THE NETHERLANDS	Tel: 31 346 334340 Fax: 31 346 351899 Email: M.Holewijn@NLRGC.antenna.nl	Author Participant
Col. Wieslaw KOWALSKI M.D., Ph.D.	Wojskowy Instytut Medycyny Lotniczej Ul. Krasinkiego 54 Warsawa 01-755 POLAND	Tel: 48 22 6852 612 Fax: 48 22 6852 715	Author Participant
Prof. med. Mieczysław WOJTKOWIAK M.D.	Wojskowy Instytut Medycyny Lotniczej Ul. Krasinkiego 54 Warsawa 01-755 POLAND	Tel: 48 22 6852 684 Fax: 48 22 6852 715	Author Participant

NAME	ADDRESS	TEL/FAX/E.MAIL	ROLE
Maj. Per Gunnar LARSSON M.D.	Swedish Armed Forces HQ Air Force Staff S-10785 Stockholm SWEDEN	Tel: 46 8 788 7628 Fax: 46 8 788 7932	Author Participant
Squadron Leader Nic GREEN M.D.	RAF School of Aviation Medicine Farnborough Hants, GU14 6SZ UNITED KINGDOM	Tel: 44 1252 394057 Fax: 44 1252 392620 Email: 100325.636@compuserve.com	Panel Member Author Participant
Col. Douglas IVAN USAF, MC, CFS	Chief Ophthalmology Branch AL/AOCO 2507 Kennedy Circle Brooks AFB, Tx 78235-5117 USA	Tel: 1 210 536 3241 Fax: 1 210 536 5165 Email: ivan.@aoc.brooks.af.mil	Panel Member Presentor Participant
Dr John PATTERSON USAF, Ph.D.	AL/AOCN 2507 Kennedy Circle Brooks AFB, Tx 78235-5117 USA	Tel: 1 210 536 3537 Fax: 1 210 536 3349 Email: patterson@alaoc.brooks.af.mil	Presentor Participant
Col. Gary SABOE USAF, M.D.	AL/HSC 2507 Kennedy Circle Brooks AFB, Tx 78235-5117 USA	Tel: 1 210 536 3475 Fax: 1 210 536 2153 Email: saboeg@diamond.brooks.af.mil	Presentor Participant
Cdr David McGOWAN USN, M.D.	NAWC (M/S 15) P O Box 5152 Warminster, PA 18974-0591 USA	Tel: 1 215 441 3203 Fax: 1 215 441 2088 Email: mcgowand@dfs.nadc.navy.mil	Workshop Deputy Chairman Author Participant
WORKSHOP CO-AUTHOR (LtCol. Tachibana's paper)			
Maj. Shinichi NISHIBE M.D.	JASDF Aeromedical Laboratory 9-7-45 Akasaka, Minato-Ku Tokyo 10 JAPAN	Tel: 03 3746 1496	Co-Author (did not attend)

AGARD AEROSPACE MEDICAL PANEL WORKSHOP MEDICAL SCREENING OF SUBJECTS FOR ACCELERATION AND POSITIVE PRESSURE BREATHING

INTRODUCTION WORKSHOP RATIONALE AND OBJECTIVES OCCUPATIONAL MEDICAL CONCERNS

Commander Gary Gray

Subjects for acceleration and positive pressure breathing research are generally a carefully screened and highly select group. Most NATO laboratories carrying out such research have a pool of subjects from whom volunteers are solicited for particular research protocols. Given the nature of such research, these subjects are often exposed to repeated high levels of +Gz, and accumulate G-dosages that exceed those of many operational pilots. Subjects also participate in equipment evaluations and trials which assess new generation life-support equipment. These trials often involve exposure to extended G-envelopes well beyond those currently used operationally. As well, subjects may be exposed to high levels of positive pressure breathing for altitude protection (PPB) or G-protection (PPG).

Both because of the ethical issues related to such research and concern for their well-being, these subjects are generally carefully medically screened both on initial selection and during periodic follow-up.

These subjects therefore constitute a highly studied group in whom G-exposure may be at least roughly quantified, and in whom statistical analysis of collective data may provide evidence as to the acute or chronic effects of +Gz and/or positive pressure breathing.

The problem for most NATO research facilities in analyzing collective data on such subjects is the small number of subjects at each facility. The concept is

appealing of pooling data from the various NATO facilities involved in acceleration research to answer important occupational health concerns with respect to exposure to high sustained G and positive pressure breathing. The Aerospace Medical Panel initiated this Workshop to explore this possibility.

Workshop Objectives

The objectives of the Workshop were:

- a. to assemble and to create a discussion format for medical monitors from the various NATO facilities conducting research in acceleration and positive pressure breathing.
- b. to identify medical and aeromedical occupational concerns with respect to current and future protocols for acceleration and positive pressure breathing research
- c. to develop AGARD/AMP consensus guidelines for medical screening and monitoring of subjects for such research.
- d. to create a registry of medical events in NATO centrifuges and a reporting system for cataloguing such incidents.
- e. to explore the feasibility of utilizing the collective AGARD denominator of NATO centrifuge subjects to address the medical concerns of +Gz and PPB by pooling medical data and collaborating in common research protocols.

MEDICAL CONCERNS WITH RESPECT TO ACCELERATION AND POSITIVE PRESSURE BREATHING

A great deal of information already exists with respect to exposure to acceleration and positive pressure breathing, involving both human and animal subjects. Much of this is reassuring but certain concerns remain or have evolved both because of what has been observed and is known, but more often because of what is not known. With continuing expansion of the operational G-envelope with future generation fighters, current acceleration subjects are being exposed to G-profiles hitherto unexplored, profiles which will be flown by the next generation of fighter pilots.

Although it is apparent that physiologic limitations in the Gz axis are more restrictive than in the Gx axis, at least for the upcoming generation of fighter aircraft, designers continue to place aviators in the Gz axis for direct visualization of target acquisition. Evolution of Gx positioned aviators awaits the progression of children of the arcade and virtual reality world into dominant positions in aircraft design.

In the meantime, for the current and next generation flight surgeons, human limits in the Gz axis remain the focus of concern. These concerns involve several organ systems known or suspected to be most sensitive to extreme Gz. These include:

- the respiratory system,
- the cardiovascular system
- the musculoskeletal system particularly the axial spine
- the central nervous system
- the special senses

Respiratory System

Dr. Earle Wood has long warned that the lungs are the most probable limiting factor in tolerance to G, particularly in the

Gz axis, and has termed them our "Achilles heel" in the G environment (ref 1). The physics of the specific gravity differential between the gas and fluid/tissue compartments of the lung dictates a downward displacement of the higher specific gravity tissue compartment with +Gz. This displacement will, at some finite level of G, eventually result in alveolar disruption. The precise G limit of the air filled lung has not been defined. However, lung disruption with pneumomediastinum has occurred in a human subject with acceleration levels as low as 5.5Gx (ref 2). Chest discomfort and uncomfortable breathing is a common sensation of subjects exposed to very high levels of +Gz eg +12Gz (personal observation, DCIEM centrifuge subjects).

Positive pressure breathing creates an additional stress by further distending lung tissue. Although with appropriate counterpressure, no evidence of overall lung over-distension has been found (ref 3), regional disparity may occur and result in lung disruption.

Pneumomediastinum has been observed in subjects of positive pressure breathing experiments with PPB levels of 70mmHg (personal observation, in publication), within the range of those currently used operationally for PPG.

In addition to the concern about the acute effects of acceleration and positive pressure is the possibility that recurrent, chronic exposure may cause tissue disruption, with bulla formation. With the current introduction of PPG/anti-G life-support equipment, exposure to high levels of positive airway pressure will no longer be a rare emergency procedure but a routine part of flying for fighter aircrew. No large systematic study using sensitive technology such as CT scanning has addressed this potential concern.

Cardiovascular System

Most acceleration research is directed to investigation of the rapid changes in the cardiovascular system and to design and test life-support equipment to support the cardiovascular system at ever higher levels of +Gz and during G-transitions.

Quite apart from these operational questions, from an occupational medical standpoint there is a concern as to whether repeated exposure to repetitive high sustained G, especially when combined with PPG, might have a deleterious effect on the heart. There are rapid changes in cardiac pre-load and afterload with G onset and offset. PPG and the anti-G straining maneuver may intensify these changes, although in a miniature swine animal model, Burns et al demonstrated that the concurrent increase in pleural pressure minimizes the transmural pressure gradient changes (ref 4). However, similar respiratory and skeletal muscle straining maneuvers in weight-lifters have been demonstrated to be associated with structural cardiac changes (ref 5). Ventricular dysfunction with positive pressure breathing was demonstrated by Cassidy in 1979 (ref 6).

In miniature swine exposed to acceleration, subendocardial hemorrhages were noted (ref 7) although these findings were later attributed to the catecholamine stress of handling the animals (ref 8). However, animals exposed to repeated stress over six months showed evidence of myocardial scar tissue (ref 9).

In human subjects, in a preliminary study, Ille et al (ref 10) demonstrated right ventricular and left atrial enlargement in a group of Mirage 2000 pilots compared with control transport pilots. In a study of Belgian F-16 pilots, Vandenbosch and Vastesaegeer (ref 11) found no serial changes over a 5 year period. However, the preliminary French findings led the Aerospace Medical Panel to create an echocardiographic Working Group to study current NATO fighter pilots for long-term structural cardiac

changes. Working Group 18 recently presented their findings (ref 12), and concluded that in the current generation of NATO fighter pilots there was no evidence of a sustained cardiac structural or functional effect from flying HSG aircraft. They noted that their conclusions were limited to the resolution of the echocardiographic technology and to the G exposure of current NATO pilots, and may not be extrapolated to pilots of the next generation of fighter aircraft. In this regard, the present cadre of NATO acceleration subjects are currently testing the life-support equipment which will be deployed in the new fighters, and in doing so are being exposed to G-envelopes beyond those currently used operationally.

In addition to the concern about possible cardiac structural changes, +Gz is known to be arrhythmogenic, with atrial and ventricular ectopic activity commonly observed in centrifuge subjects for training or research. The arrhythmogenesis is due to both the marked fluctuations in autonomic tone with G-loading and offloading, as well as changes in preload affecting atrial dimensions. More serious arrhythmias including ventricular tachycardia, atrial fibrillation, and S-A blocking have been observed and associated with G-induced loss of consciousness (ref 13)

Musculoskeletal System

Injuries to the musculoskeletal system are the most commonly recognized sequelae to HSG flying. The cervical spine is particularly prone with neck pain reported in up to 75% of F-16 and F-18 fighter pilots, most commonly due to muscular strain but with injuries documented including compression fractures, spinous process fracture, and herniated discs (ref 14, 15, 16). Interestingly, low back pain has not been found to be more prevalent in centrifuge subjects (17). An unusual case of fracture of the femur occurring during centrifuge acceleration has been reported (18)

Muscular stiffness and discomfort is a common complaint in subjects and trainees following acceleration exposure in human centrifuges, and a case of acute myoglobinuria due to massive muscle tissue damage has been documented (19).

The AGARD Aerospace Medical Panel is addressing the concern about cervical spine injuries in NATO aircrew through a Working Group.

These cervical spine problems appear to be more prevalent in operational aircrew than in centrifuge subjects, possibly because of the head movement required under G to monitor for aggressors. However, centrifuge subjects are being exposed to G-levels that exceed operational limits in current fighter aircraft. The potential for injury, particularly to the axial spine increases with G-loading and onset rates, both increasing in modern centrifuges. A high incidence of herniated discs have been found on MRI in regular centrifuge subjects although the significance of these asymptomatic MRI findings is unclear (ref 20).

Neurologic System

G-induced loss of consciousness (G-LOC) is a potential risk in all acceleration protocols, and many subjects in acceleration research have repeatedly experienced G-LOC. Whether or not there are any long term sequelae to recurrent G-LOC is not known although there have not been any cognitive effects demonstrated. However, neither have there been any long-term serial or even cross-sectional studies of cognitive function in acceleration subjects with recurrent G-LOC.

In 1989, the Aerospace Medical Association convened a panel of experts to address the concerns and deliberate the ethics of deliberate G-LOC experiments (ref 21). The conclusion of the Panel was

that there was no evidence at present of long-term sequelae from repeated G-LOC, but acute and long-term follow-up of subjects experiencing G-LOC was recommended to look for any evidence of an evolving organic mental syndrome.

No such studies have been carried out and would be an important area to address for an AMP Working Group.

Special Senses

There is a concern that rapid-onset / high sustained G may cause damage to the eye, or vestibular system. In high myopes, because of commonly associated retinal pathology, retinal detachment is a concern with high G-levels. There is little data in this area, but with exposure of centrifuge subjects to extremes of acceleration, there is a need for serial follow-up and monitoring for structural or functional changes in the eye and vestibular system.

REFERENCES:

1. Wood EH, Hoffman EA. The lungs, "Achilles heel" of air breathers in changing gravitational-inertial force environments. *Physiologist*. 1984; 27: 47-8.
2. Wood EH. Potential hazards of high anti-Gz suit protection. *Aviat. Space Environ. Med.* 1992; 63: 1024-26.
3. Green, NA. Lung volume changes under positive pressure breathing for G protection. Royal Air Force Report 01/95, RAF/School of Aviation Medicine, Farnborough, UK
4. Burns JW, Fanton JW, Robinson JL. The influence of the AGSM, PBG, and anti-G suit inflation on thoracic hemodynamics during +Gz in swine. *J. Gravit. Physiol.* 1994; 1; 48-51

5. Deligiannis A, Zahopoulou E, Mandroukas K. Echocardiographic study of cardiac dimensions and function in weight lifters and body builders. *Int J. Sports Cardiol*, 1988; 5: 24-32.
6. Cassidy S, Esenbacher WL, Robertson CH, Nixon JV, Blomqvist G, Johnson RL. Cardiovascular effects of postive-pressure ventilation in normal subjects. *J. Appl. Physiol.: Resp. Environ. Exercise Physiol.* 1979; 47; 453-61.
7. Burton RR, MacKenzie WF. Heart pathology associated with exposure to high sustained +Gz. *Aviat. Space Environ. Med.* 1975; 46: 1251-3.
8. Burns JW, Laughlin MH, Witt WM, Young JT, Ellis JP Jr. Pathophysiologic effects of acceleration stress in the miniature swine. *Aviat Space Environ Med* 1983, 54; 881-93.
9. Laughlin MH. An analysis of the risk of human cardiac damage during +Gz stress: a review. *Aviat Space Environ Med.* 1982; 53: 423-31.
10. Ille H, Didier A, Allegrini N, Maurel C. Selection et Surveillance Medicales des pilotes de Mirage 2000: apport de l'echocardiographie. AGARD Conference Proceedings Medical Selection and Physiologic Training of Future Fighter Aircrew: CP-396, 1985; 32-1 - 32-13.
11. Vandenbosch PA, Vastesaege JP. A longitudinal study of echocardiographic parameters by F-16 pilots. *Aviat. Space Environ. Med.* 1989; 60 (pages)
12. Vandenbosch P. Report of the AGARD (NATO) Echocardiographic Working Party. Abstract 4, 67th Annual Scientific Meeting of the Aerospace Medical Association, Atlanta, Georgia.
13. Tachibana S, Tomomitsu A, Nakamura A, Shekiyuki Y. Serious arrhythmias coinciding with alteration of consciousness in aircrew during +Gz stress. *Aviat. Space Environ. Med.* 1194; 65: 60-6
14. Knudson R, McMillan D, Doucette D, Seidel M. A comparative study of G-induced neck injuries in pilots of the F/A 18, A-7 and A-4. *Aviat. Space Environ. Med.* 1988; 59: 758-60
15. Schall DG. Non-ejection cervical injuries due to +Gz in high performance aircraft. *Aviat. Space Environ. Med.* 1989; 60: 445-56.
16. Kikukawa A, Tachibana S, Yagura S. G-related musculoskeletal spine symptoms in Japan Air Self-Defence Force F-15 pilots. *Aviat. Space Environ. Med.* 1995; 66: 269-72.
17. Voge VM, Tolan G. Back injury related to acceleration profiles. Abstract #3, 64th Annual Scientific Meeting, 1993 Aerospace Medical Association, Toronto.
18. Reid ME, Han JS. Fracture of the femoral neck sustained during routine centrifuge training. Abstract 180, 63rd Annual Meeting, Aerospace Medical Association, 1992, Miami, Florida.
19. McGowan D, Whinnery J, Gillingham K, Maggio F, Gray G. A review of acceleration injuries on human centrifuges in the United States and Canada since 1985. Abstract 181, 63rd Annual Scientific Meeting of the Aerospace Medical Association, 1992, Miami, FL.
20. Burns JW, Loecker TH, Fischer JR JR., Bauer DH. Prevalence and significance of spinal disc abnormalities in an asymptomatic acceleration subject panel. *Aviat. Space Environ. Med.* 1996; 67:849-53
21. Burton RR, Werchan PM, Burns JW, Fanton JW, Dollins AB, Whinnery JW, Jones DR, Euretig JG, Hickman JR. Panel on G-LOC. *Aviat. Space Environ. Med* 1991; 62: 609-638.

THE CANADIAN REPORT

A. MEDICAL SCREENING OF ACCELERATION AND PPB RESEARCH SUBJECTS

B. MEDICAL OCCURENCES IN ACCELERATION/PPB RESEARCH SUBJECTS

Cdr G.W. Gray and LCdr W.A. Bateman

Defence and Civil Institute of Environmental Medicine (DCIEM)

Toronto, Canada

A. MEDICAL SCREENING

INTRODUCTION

With the completion of the new centrifuge facility in 1988, DCIEM established a pool of volunteers who were medically screened for research protocols involving acceleration ($>+5Gz$), high altitude chamber exposures ($>10,000$ feet) or positive pressure breathing (PPA/PPG >30 mmHg). This group was called the "A" team, and has 38 members, including 15 currently active.

The aim of A-Team medical screening is to identify medical conditions that might be adversely affected by the stress of the altitude, pressure breathing or high-G environments. Although the subject's welfare is the primary aim of this screening, since little is known about physiologic responses and medical complications in these realms, the results of this surveillance are germane to research as well.

Individuals interested in participating in A-Team activities are medically screened, and if fit, they become A-Team members. They may then volunteer for individual protocols. They are not obliged to participate in any particular study just because they are A-Team members. Periodic medical surveillance is carried out on all active members.

SUBJECT CHARACTERISTICS

Of the 38 A-Team members, 15 are civilian and 23 military, including 3 military pilots. The 15 civilians consist largely of Defence Scientists, research assistants and technicians working at DCIEM.

Table 1: The DCIEM A-team

Age	range: 21-49
Duration of participation	range: 3 months to 9 years
Gender	3 female; 35 male
Number of centrifuge runs	0-100: 25 100-500: 7 500-1000: 4 >1000: 4
Number of altitude chamber runs	range: 0-60
Max PPA	88 mmHg
Max PPG	80 mmHg
Max +Gz	12.0
Max altitude	80,000 feet

MEDICAL SCREENING

Selection Screening

The following investigations are obtained on all individuals volunteering for the A-Team:

- a. clinical examination
 - aeromedical questionnaire
 - physical examination
- b. ophthalmologic examination
 - cycloplegic refraction and dilated funduscopy
 - intra-ocular pressure
 - visual fields (Humphrey)
- c. audiogram
- d. maximum exercise stress test
- e. echocardiogram/Doppler
- f. pulmonary function testing
- g. x-rays
 - chest x-ray
 - spinal column
- h. electroencephalogram

i. laboratory

- CBC, PTT, INR
- liver, kidney, thyroid function
- glucose, lipids
- urinalysis

Periodic Screening**ANNUAL**

- clinical examination
- resting 12 lead ECG
- echocardiogram/Doppler
- PFTs (FVC); full PFTs for PPB
- audiogram
- laboratory tests as done initially

EVERY TWO YEARS

- chest x-ray
- ophthalmologic assessment

Specialized Screening

The following specialized screening procedures were introduced in 1996:

- CT Scans of lungs
high resolution CT scanning on initial evaluation and every two years
- MRI/ brain and neck
on initial evaluation and every 3 years
- Magnetic Resonance Imaging
initial evaluation only
- Neuropsychiatric Testing
on initial evaluation and every two years

B. MEDICAL OCCURENCES

There have been a number of medical occurrences observed on the DCIEM centrifuge and in relation to positive pressure breathing. These include:

RESPIRATORY

- pneumomediastinum related to pressure breathing experiments

CARDIOVASCULAR

- cardiac arrhythmias
 - supraventricular tachycardia
 - atrial fibrillation
 - ventricular tachycardia
 - sinoatrial block
- ? diastolic dysfunction

MUSCULOSKELETAL

- herniated cervical discs (MRI finding)
- acute myoglobinuria

MISCELLANEOUS

- Post-concussion syndrome
- Hemorrhoids
- Motion sickness

Respiratory Occurences**Pneumomediastinum/
Pulmonary Barotrauma**

During a University research contract to assess the effects of positive pressure breathing, five subjects (not A-team members) were exposed to 30 mmHg unassisted positive pressure breathing and 70 mmHg assisted PPB. The fourth subject so exposed noted some mild retrosternal discomfort and cough afterwards, and a chest x-ray showed a pneumomediastinum. Because of this occurrence, a chest x-ray was done on the fifth subject immediately after the exposure, and again a pneumomediastinum was demonstrated. Both subjects recovered without sequelae.

The observation of these two occurrences of pneumomediastinum raised the question as to whether operational levels of PPG might damage the lung. DCIEM recently carried out further experimentation to clarify the significance of this observation. 8 subjects were studied with chest x-rays two hours

following 70mmHg APPB combined with 8 sequential exposures to +6Gz for 15 seconds, and again after 2 minutes of UAPPB at 30 mmHg. No occurrence of pneumomediastinum or pneumothorax was noted in these subjects.

17 DCIEM "A" team subjects with various exposure to PPB (max 80 mmHg), and +Gz (max 12 Gz) have undergone high-resolution CT scans of the chest, with no significant findings.

Cardiovascular

Diastolic Dysfunction?

In 1995, Gray (Aviat Space Environ Med 1995; 66: 463 - abstract) showed a higher prevalence of mitral regurgitation and E/A mitral flow reversal after Valsalva in DCIEM "A" team subjects, suggesting possible diastolic dysfunction. However, this observation needs to be reviewed in a larger subject pool.

Rhythm Disturbances

ATRIAL FIBRILLATION: A 23 year old pilot (not an A team member) developed atrial fibrillation (AF) after a 5/30 ROR profile while undergoing centrifuge training. He remained in AF with a slow ventricular response ~80bpm overnight, and reverted the next day after two oral doses of digoxin 1 mg. A non-invasive cardiologic work-up was normal, including echo, Holter and stress test. He was an extremely fit individual with a high resting vagal tone. He completed a repeat centrifuge evaluation, with no AF but a period of junctional rhythm rate 53 following a 6/15 ROR. He was returned to full flying duties but was advised to decrease his aerobic training to a less intense level.

VENTRICULAR TACHYCARDIA: A 28 year old female DCIEM "A" team member developed a self-limiting run of ventricular tachycardia during a straining GOR. She had been regularly screened and was normal from a cardiovascular standpoint. Repeat echo, Holter and EST

were normal. She continued as a centrifuge subject with no further episodes of ventricular tachycardia.

Musculoskeletal:

Acute Rhabdomyolysis

A 26 year old male pilot developed acute rhabdomyolysis with marked muscle aching and tenderness, myoglobinuria and extremely high muscle enzyme levels (CK>3000) the day following centrifuge training. This resolved with rest and high oral fluid intake. Investigations including a muscle biopsy and muscle enzyme assays demonstrated no specific muscle enzyme deficiency. He returned to full flying duties and had no further episodes of rhabdomyolysis.

Herniated cervical discs

Two asymptomatic DCIEM "A" team subjects showed a definite disc herniation on MRI scanning of the neck. Both subjects were reviewed by a neurosurgeon and following clinical review and MRI review, were advised against further centrifuge exposure.

Miscellaneous Other Events

Post-concussion syndrome

A male Flight Surgeon trainee experienced G-LOC in the centrifuge (before the use of protective helmets became mandatory), struck his head and sustained a scalp laceration and suffered post-concussional headaches for several months afterwards. No employment restrictions ensued.

Hemorrhoids

A number of "A" team members have commented that high-G experiments have exacerbated hemorrhoids.

Persistent Motion Sickness

We have observed several individuals who developed symptoms of motion sickness in the gondola which persisted for many hours after being removed from the gondola

Examens Médicaux Concernant les Personnes se Prêtant à des Recherches Biomédicales Sans Bénéfice Direct au LAMAS.

Colonel J.M. Clère, M.C., Ph.D, Laboratoire de Médecine Aérospatiale
Centre D'Essais en Vol, Brétigny sur Orge Cedex
France

INTRODUCTION

Dans le cadre des recherches biomédicales sans bénéfice direct pour les personnes, qui sont menées au Laboratoire de Médecine Aérospatiale (LAMAS) du Centre d'Essais en Vol (CEV), il est nécessaire que les responsables d'essais humains s'assurent de l'intégrité physiologique des personnes qui se prêtent à ces recherches. Ces personnes, volontaires, appartiennent au personnel militaire de carrière et au personnel civil du CEV, parfois à d'autres organismes de la Défense. La présente note de service a pour objet de fixer les examens médicaux auxquels ils doivent être soumis avant toute expérimentation.

Ces examens sont différents selon les essais réalisés.

Toutes les personnes participant à une expérimentation doivent avoir subi une visite médicale définissant leur état de santé. Certaines fonctions physiologiques sont particulièrement examinées pour définir soit une absence de contre-indication médicale, soit une aptitude spécifique par rapport à une norme préexistante pour les personnels de l'aéronautique militaire (par exemple la norme spécifique "siège éjectable").

1. EXAMENS MEDICAUX NON SPECIFIQUES

Les personnes se prêtant à des recherches biomédicales doivent avoir subi au centre médical de la base d'essais de Brétigny, l'examen médical suivant:

avec une périodicité annuelle:

- examen clinique complet,

- électrocardiogramme de repos,

- analyse d'urine avec recherche d'hématies et de protéines;

à l'admission comme sujet d'expérience puis, au cours des visites suivantes, selon la demande du médecin examinateur:

- radiographie pulmonaire,

- un bilan sanguin à la recherche de facteurs athérogènes.

Le médecin examinateur peut demander des explorations complémentaires.

2. EXAMENS MEDICAUX SPECIFIQUES

Ces examens sont réalisés en complément des examens non spécifiques. Il s'agit d'examens modulés en fonction des contraintes expérimentales. Ils sont pratiqués au Centre Principal d'Expertise Médicale du Personnel Navigant (CPEMPN) ou au Service de Médecine Aéronautique (SMA) du Service de Santé des Armées.

2.1. Expérimentation en centrifugeuse.

2.1.1 Pour tout niveau d'accélération

Les personnes participant à une expérimentation doivent posséder l'aptitude siège éjectable (CPEMPN). Cette aptitude est définitive, sauf événement pathologique intercurrent.

2.1.2 Pour tout niveau d'accélération supérieur ou égal à 7 G:

Les examens suivants sont exigés:

- échocardiographie dans les mêmes conditions que celle qui est pratiquée pour les pilotes de Mirage 2000 (CPEMPN),

- enregistrement de 24 heures de type Holter (SMA ou CPEMPN),

- épreuve d'effort (SMA),

- examen ophtalmologique.

Ces examens sont pratiqués tous les cinq ans pour les personnes d'âge inférieur à 40 ans et tous les 2 ans pour les personnes d'âge supérieur ou égal à 40 ans.

2.2. Expérimentations sur le siège vibrant.

Les personnes participant à ces expérimentations doivent posséder l'aptitude siège éjectable (CPEMPN).

2.3. Expérimentations en caisson d'altitude.

2.3.1 Situation de décompression lente

- examen ORL comportant un audiogramme (centre médical de la base d'essais de Brétigny).

Cet examen est effectué avec une périodicité de 5 ans.

2.3.2 Situation de décompression rapide ou explosive

Outre les examens décrits en 2.3.1, l'examen suivant est pratiqué:

- une exploration fonctionnelle respiratoire (SMA), particulièrement orientée vers la mesure des résistances bronchiques.

Cet examen est pratiqué tous les cinq ans pour les personnes d'âge inférieur à 40 ans et tous les 2 ans pour les personnes dont l'âge est supérieur à 40 ans.

2.4. Expérimentations avec utilisation de la ventilation en pression positive (PPB) à une valeur de surpression supérieur à 4 kPa.

En plus de l'aptitude médicale non spécifique, il est nécessaire que le sujet d'expérimentation subisse:

- une exploration fonctionnelle respiratoire (SMA),

- un examen ORL avec audiogramme (centre médical de la base d'essais de Brétigny),

- une échocardiographie,

- un examen ophtalmologique.

Ces examens sont pratiqués tous les cinq ans pour les personnes d'âge inférieur à 40 ans et tous les 2 ans pour les personnes dont l'âge est supérieur à 40 ans.

2.5. Expérimentations avec utilisation d'une charge de travail physique supérieure à 70 p. cent de la capacité maximale aérobie et expérimentations en immersion en eau froide ($T \leq 15^{\circ}\text{C}$)

En plus de l'aptitude médicale non spécifique, il est nécessaire que le sujet d'expérimentation subisse:

- une épreuve d'effort (CPEMN ou SMA).

Cet examen est pratiqué tous les cinq ans pour les personnes d'âge inférieur à 40 ans et tous les 2 ans pour les personnes dont l'âge est supérieur à 40 ans.

3. DECISION.

La décision d'inclure un sujet humain dans un protocole d'expérimentation biomédicale sans bénéfice thérapeutique direct est prise par le Médecin -Chef du CEV et du LAMAS.

4. DOSSIERS.

Les dossiers médicaux des personnes qui participent aux essais physiologiques sont détenus par le médecin-chef du LAMAS. Un fichier des personnels avec mention de la classe d'aptitude et de la péremption correspondante est détenu par l'agent chargé de la coordination technique des essais qui, d'autre part, centralise les renseignements concernant les assurances des personnels civils participant aux expérimentations. Les dossiers médicaux eux-mêmes sont détenus dans le coffre du médecin-chef du LAMAS.

CURRENT STATUS OF SUBJECTS IN JASDF AEROMEDICAL LABORATORY

Lt.Col Shoichi Tachibana, MD, PhD JASDF Air Staff Office

Major Shinichi Nishibe, MD JASDF Aeromedical Laboratory

1. Initial Physical screening for subject candidates

- (1) cervical X-ray
4 films: frontal, lateral, 2 obliques
- (2) lumbar X-ray
4 films: frontal, lateral, 2 obliques
- (3) ECG (resting and stress)
- (4) blood pressure (resting and stress)
- (5) ordinary aeromedical examination

2. Physical check before centrifuge ride

- (1) interview by physician
- (2) body weight
- (3) resting ECG and HR

3. Medical monitoring during centrifuge ride

- (1) ECG
- (2) HR
- (3) respiratory curve
- (4) digital blood pressure

4. Physical check after centrifuge ride

- (1) interview by physician
- (2) resting ECG and HR

5. Number of centrifuge subjects

Year	Registered of Rides	Participant's Number	Number
1995	35	14	28
1994	25	14	40
1993	14	7	59
1992	24	9	76
1991	25	9	48
1990	20	9	86

6. Injuries

- (1) one case of cervical disk herniation
(42 year old male subject)
- (2) one case who developed multifocal PVCs during acceleration was disqualified for subject

7. Current centrifuge study

- (1) study of cerebral blood flow by an instrument using doppler effect
- 2) feasibility study of COMBAT EDGE PPG system

MEDICAL INCIDENCES DURING CENTRIFUGE TRAINING AND F-16 FLYING IN THE NETHERLANDS

M. Holewijn
Department of Research and Development
Netherlands AeroMedical Centre (NAMC)
3769 ZG Soesterberg
the Netherlands
tel: +31.346.334340
fax: +31.346.351899
e-mail: M.Holewijn@nlrgc.antenna.nl

SUMMARY

A survey in the NAMC database containing the records of centrifuge runs of candidate and experienced pilots revealed that in 15.1 % of the centrifuge training sessions, a run was stopped. The major reasons were motion sickness (31 %), fatigue (28 %), and arrhythmias (22 %). During centrifuge training at the NAMC the prevalence of an episode of supra ventricular ectopies was 33 %. In 21 % of the runs a ventricular ectopie occurred.

In-flight ECG monitoring revealed that arrhythmias occurred in 62 % of the pilots (n=40). These arrhythmias were premature ventricular contractions in 49 %, premature atrial contractions in 41 %, ventricular bigeminy periods in 8 %, ventricular couplets in 5 %, supra ventricular tachycardia in 3 % of the pilots. A combination of arrhythmias were found in 27 % of the pilots. The number of pilots showing arrhythmias at $+G_z$ -levels $<3G$ did not increase at $+G_z$ -levels $>3G$. However, the number of premature ventricular contractions significantly increased at $+G_z$ -levels $>3G$. This effect on the number of premature atrial contractions was not found.

INTRODUCTION

Pilots of high performance fighter aircraft have to tolerate G levels for considerable periods of time. Therefore, it is generally accepted that fighter aircraft crew members should be trained in a safe environment to improve their skills in performing the anti-G straining manoeuvre (AGSM) and to familiarize in the use of high-G protective equipment.

In order to train Dutch and Allied pilots the NAMC's human centrifuge has been used since 1983. The NAMC's centrifuge can generate 20 G at onset rates of 3.5G/sec and is equipped with a computer generated outside world projected on a large screen in front of the subject. The free-swinging gondola is equipped with a F-16 type seat and life support equipment, a side stick operated F-16 simulation model, two-way audio communication and extensive medical instrumentation.

A go- no go switch is located on the simulated throttle quadrant. Medical and physiological data are stored on tape and selected channels are recorded on a paper strip chart. The (candidate) pilot is monitored by a video camera mounted in the gondola and online two lead ECG is recorded for the qualified physician on-site. The analysis of the centrifuge ECG data will be described in this paper and the prevalence of arrhythmia will be compared with the in-flight prevalence.

TRAINING

The NAMC High Sustained G (HSG) Course was developed by Royal Netherlands Air Force in response to increasing awareness of the need to prepare aircrew for the stresses of the high-G environment of modern high-performance fighter aircraft. Until now, 3100 (candidate) pilots of different Allied nations were trained.

The primary HSG course objectives are an increase in the G tolerance resulting from an improved skill in performing the anti-G straining manoeuvre and to provide life experience with the effects of the High-G environment. All Dutch (candidate) pilots have to pass the 8 G profile for 15 seconds.

The one-day course includes interactive classroom sessions and several G training sessions. The centrifuge training sessions include three "core" profiles:

- a gradual-onset rate (GOR) run to establish the student's relaxed and straining G-tolerances;
- a rapid onset rate (ROR) run to 6 G for 30 sec, enabling practice of the AGSM; and
- a ROR run to 8 G for 15 sec, simulating extreme operational exposures.

Trainees may then elect to experience two simulated air-combat manoeuvre (SACM) profiles in the centrifuge. The NAMC HSG Course conforms to NATO STANAG 3200 (HSG Training).

MEDICAL SCREENING

All military trainees must meet the Class 1 medical

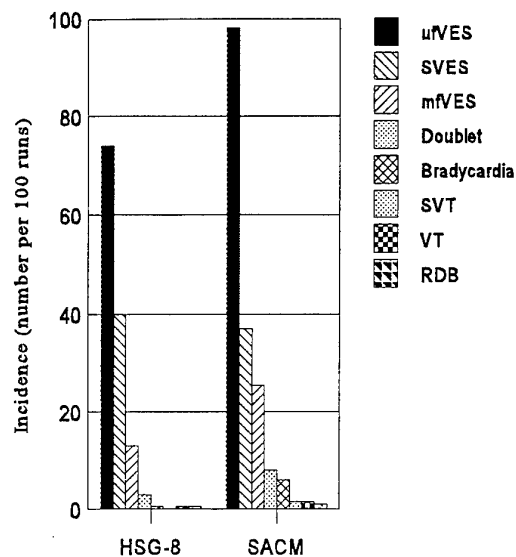


Fig. 1. The incidence of arrhythmias during centrifuge training with a HSG-8 or a SACM profile.

SVES: supraventricular extra-systole; SVT: supraventricular tachycardia; uVES: uni focal ventricular extrasystole; mVES: multi focal ventriculaire extrasystole; VT: ventricular tachycardia; RDB: rate dependent block.

standards required for flying high performance aircraft. Those suffering from medical conditions which may adversely affect centrifuge training are excluded, until medically fit. Subjects participating in research projects are subjected to the same medical standards.

STOP CRITERIA

The safety of the (candidate) pilot is a prime consideration in High-G centrifuge training. At the NAMC the following stop criteria during centrifuge training runs are used;

- release of the go- no go button
- heart rate > 200 beats per minute
- arrhythmias such as
 - multi focal premature ventricular contractions (PVC),
 - 2 or more sequential PVC's,
 - ventricular tachycardia, or doublets,
 - supra ventricular tachycardia,
 - relative bradycardia
- chest pain
- G-induced loss of consciousness

If a centrifuge run has been stopped the operations team decides, depending on the situation, in collaboration with the trainee if the training is to be continued. A record is kept of all reasons for stopping a centrifuge run.

TYPES OF MEDICAL GROUNDS FOR STOPPING A CENTRIFUGE RUN

A survey in the database containing the records of centrifuge runs of candidate and experienced pilots revealed that in 15.1% of the centrifuge training sessions, a run was stopped. The major reasons were motion sickness (31 %), fatigue (28%), and arrhythmias (22%) (Table 1).

Table 1. Grounds for stopping a centrifuge training run.

	trainees (%)	occurrence (% of runs stopped)
motion sickness	4.7%	31%
fatigue	4.3%	28%
arrhythmias	3.3%	22%
G-LOC	1.4%	9.5%
other	1.4%	9.5%

Only in 1.4 % of all the training sessions a G-LOC occurred.

ARRHYTHMIAS DURING CENTRIFUGE TRAINING

The majority of the trainees in the NAMC are EKG monitored so a large database is available of EKG recordings for the different types of centrifuge training runs. In order to investigate the incidence of arrhythmias an analysis was done on the occurrence and types of arrhythmias during the training profiles with rapid onset of +G_z; the High Sustained G profile, HSG-8 (1G/s onset, 8G for 15 s) and the Simulated Air Combat Manoeuvring profile, SACM (3G/s onset and two 10s periods of 9 and 8.5 G separated with 10s period of 4G).

The analysis yielded that for the HSG-8 profile, uni focal ventricular extrasystoles (74%) and supraventricular extrasystoles (40%) had the highest incidence of episodes having one or more arrhythmias (Fig.1). Further, multi focal ventricular extrasystoles occurred in 13.2 %, doublets in 2.8 % and ventricular tachycardias, bradycardias, and rate dependent blocks were found in 0.7% of the centrifuge training runs (1). The incidence increases during the SACM profile for ventricular extrasystoles (VES) to 98 % and for supraventricular extrasystoles (SVES) it dropped to 37% (Fig. 1). Multi focal ventricular extrasystoles occurred in 25.4 %, doublets in 7.7 %, ventricular tachycardias in 1.5 %, bradycardias in 6.2%, and rate dependent blocks in 0.8% of the SACM centrifuge training runs.

It should be noted that the incidence of arrhythmias will be an underestimation due to the fact that a selection had occurred due to the fact that some pilots were

withdrawn from further training for (medical) reasons occurring in the previous training session.

All reported arrhythmias were non-sustained and no medical intervention was never necessary during or after a training session.

Table 2. Episodes of one or more arrhythmias (% of runs) during centrifuge training (8 G profile).

	SVE	VES
Krol & Holewijn (1)	33	21
McKenzie & Gillingham (2)	41	47
Whinnery (3)	44	41

The incidence of arrhythmias during training with the NAMC's centrifuge are slightly lower than the results from other studies (Table 2). An explanation could be the occurrence of muscle artifacts and misconceived P-waves.

IN-FLIGHT ARRHYTHMIAS

In order to compare the incidence of arrhythmias found during centrifuge training a field study was performed (4). Forty pilots (median age 27 years, range 22-47 years) of the Royal Netherlands Air Force underwent in-flight 3 leads ambulatory ECG recording. The $+G_z$ -load was simultaneously recorded. Measurements were performed during basic flight manoeuvre training missions.

Arrhythmias were found in 62 % of the pilots. These arrhythmias were premature ventricular contractions in 49 %, premature atrial contractions in 41 %, ventricular bigeminy periods in 8 %, ventricular couplets in 5 %, supraventricular tachycardia in 3 %, and a combination of arrhythmias in 27 % of the pilots were found. The number of pilots showing arrhythmias at $+G_z$ -levels $<3G$ did not increase at $+G_z$ -levels $>3G$. However, the number of premature ventricular contractions significantly increased at $+G_z$ -levels $>3G$. This effect on the number of premature atrial contractions was not found. Higher grades of arrhythmias (Lown ≥ 3) were exhibited by 19 % of the pilots.

Table 3. Episodes of one or more arrhythmias (% of pilots) during in-flight situations.

	SVE	VES
Krol & Holewijn (4)	49	41
Lindqvist et al. (5)	53	67
Skytta et al. (6)	16	33

From Table 3 it can be seen that in two other studies similar results are reported.

From the results of our in-flight study (4) it is concluded that higher $+G_z$ -levels do not provoke arrhythmias in more pilots, but does increase the number of premature ventricular contractions. Furthermore, the need for a stratification of arrhythmias

by operational significance will be necessary.

REFERENCES

1. Krol JR and Holewijn M. Arrhythmias during centrifuge training. Report NAMC, NLRGC 1993-K1; 1993.
2. McKenzie I and Gillingham KK. Incidence of cardiac dysrhythmias occurring during centrifuge training. *Aviation Space and Environmental Medicine*, 64, 687-691; 1993.
3. Whinnery JE. The electrographic response to high G centrifuge training. *Aviat Space Environ Med* 61:716-721; 1990.
4. Krol JR and Holewijn M. In-flight holter monitoring of F-16 pilots. Report NAMC, NLRGC 1994-K7; 1994.
5. Lindqvist, A., Skyttä, J., Aho, J., Karjalainen, J., Laitinen, L.A. (1990). Holter monitoring of jet pilots during combat flight. Unpublished data.
6. Skytta JS, Karjalainen J and Aho J. Heart rate and arrhythmias during high G flight. *Mil Med* 159:490-493; 1994.

Current selection procedures for +Gz and training methods increasing acceleration tolerance level (ATL) in Polish Air Force pilots

Col. W. Kowalski MD, PhD
Prof. M. Wojtkowiak MD, PhD
Dept. of Aviation Physiology
Polish Air Force Institute of Aviation Medicine
01-755 Warsaw. Krasińskiego Str. 54

Introduction

The examination of +Gz tolerance on the human centrifuge was first conducted in 1963. It included the examination of the candidates for military aviation, Air Force Academy students and operational pilots. Up to now they constitute the only group of subjects examined in the centrifuge. During experimental studies we do not use experimental groups but pilots-volunteers.

The basic tasks of our acceleration G-laboratory are:

- medical screening procedures for +Gz;
- routine ATL examination;
- ATL increasing training;
- experimental examinations.

Acceleration parameters used during the centrifuge examination were settled basing on the achievements of Polish operational aircraft. In 1976-7 experimental studies were started using PPB (assisted and unassisted) as the way of acceleration tolerance increase (2).

In 1990 when Mig-29 was introduced for exploitation, the studies of increasing acceleration to the level of +9Gz were started. In 1992 the centrifuge cabin was modified as well as the record of physiological parameters and psychophysiological efficacy indices in the computer system (6).

Centrifuge achievements

The centrifuge constructed in Poland has 1 arm 9 m long with suspended cabin, hanging out, weighting 600 kg. The maximum acceleration value is 16 G with onset up to 6 G/s. The centrifuge is controlled by the computer and it is possible to reproduce with utmost precision any programmed acceleration characteristics. It is possible to send from the centrifuge cabin maximum 35 information parameters from the subject. At present the following parameters are sent; EKG, HR in implicit values and in the form of a curve integrated with acceleration onset rate curve, breathing frequency, ear lobe vascular pulsation amplitude, time of reaction to visual stimuli and infrared pilot's face TV screen image. In specific cases the record of blood flow velocity changes in temporal artery, EEG, EEO and impedance rheography are made.

At present, next modification of the cabin is carried out creating the possibility of:

- changing the angle of chair placement,
- controlling centrifuge drive by the subject from the centrifuge,
- subject's observation of the tests: psychological, acceleration profile, etc. on the monitor screen.

Programs of centrifuge examination

For many years ATL in the centrifuge has been defined in a standard way, according to 3 acceleration profiles called screenings programs for the candidates and pilots (3).

1. GOR with the onset rate of 0.1 G/s. ATL value of 5.7 G is accepted as a minimum for qualifying for air service. The maximum accepted acceleration, as the end point is, in this program 8G. According to our criteria, pilots reaching this value are considered as perfectly fit for flying on high performance aircraft.

2. "Prolonged acceleration profile". In order to define the settled acceleration values, we apply the program characterized by onset rate of 0.2

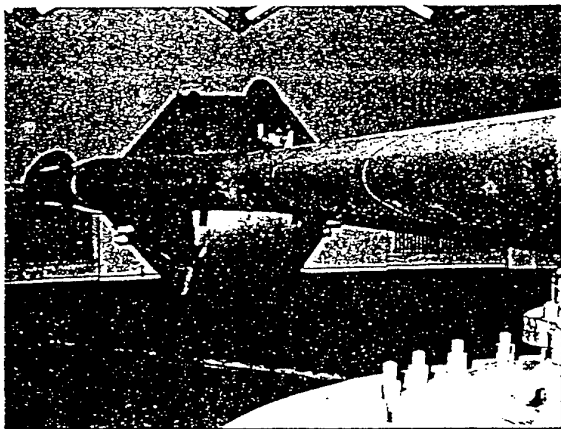


Fig.1 Polish human centrifuge

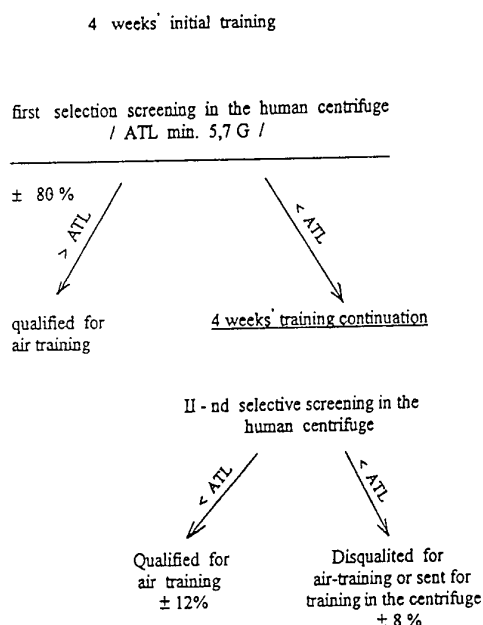
G/s to reach the maximum value of 4.5G. In this program, the subjects are evaluated according to the time of acceleration endurance without visual disturbances. The minimum value for qualifying for air service is 60s., the maximum - 5 min. (very good mark according to our criteria). This program is used for the evaluation of circulatory system compensatory reactions.

3. ROR with 1.0 G/s onset rate. The program consist of a number of intervals with the values increased stepwise by 0.5G on plateau - up to the occurrence of the peripheral vision loss. The time of Gmax is last 15 s during each interval and the breaks between each two intervals 20s. A candidate is considered perfectly fit when he reaches the value of 7.0 G. This is also the end point of our examination.

Selection of the candidates

We devote particular attention to the selection of candidates for military aviators from aviation middle school in the centrifuge(1) Fig.2.

Screening for candidates :



We start it before air training. During the period preceding the first centrifuge examination the candidates perform physical training improve the force of skeletal muscles, particularly engaged in L-1 and M-1 maneuvers. The aim of this procedure is to develop motoric features of

force and speed. To improve circulatory system adaptation to acceleration exposure the candidates are trained, twice a week on a chain carousel, with the acceleration not exceeding 2.5G. The objective of 20 min. training is to stimulate circulatory system compensatory responses.

After 4 - 6 week's training, the candidates are sent for the first examination in the centrifuge, in order to define ATL in GOR program. The ATL value of 5.7G is the minimum for qualifying for air training. The candidates who do not obtain the demanded ATL are directed again to for weeks training and then examined in the centrifuge. The candidates who do not obtain 5.7G during the second examination are disqualified. They can fly on transport aircraft, helicopters, or may be sent for centrifuge training - according to the method worked out by the authors (5).

Pilot's training for HPA

Another selection system was carried out for the pilots, who were selected „ as the best of the best" for flights on HPA.

At first, they were selected basing on routine clinical and ATL examination. The minimum ATL value in pilots qualified for the training has to be 6.6 G in GOR and 6.5 G in ROR - without anti-G suits.

The 3 weeks training was carried out in our Aviation Condition Center which is located in Zakopane 945m above sea level. In Fig.3 the special training program for pilots, is presented. Fig 3.

The training consisted of two stages.

1. The first stage included:

- physical training increasing the strength of the respiratory muscles, spinal, thigh extensors and abdominal muscles;
- respiratory exercises during L-1 and M-1 maneuvers;
- general and special gymnastics;
- physiotherapy and recreation.

At the same time, lectures were carried out , comprising the problems of aviation physiology, with particular stress put on increasing ATL. The details of this training are described in another paper (3, 7). The practical effect of this method is that pilots had master perfectly a proper sequence of L-1 and M-1 maneuvers under conditions of maximal and forced abdominal muscles straining.

In the pilots training program, the particular attention is paid to the proper coordination of the inspiratory and expiratory phases combined



Fig. 3
with abdominal muscles straining in relation to the acceleration onset moment.

2. The second stage included the L-1 and M-1 maneuvers coordinated with exposure to rapid onset rate accelerations using the centrifuge. The characteristics of the acceleration applied in this training consists of the 2 acceleration stages presented in Fig 4.

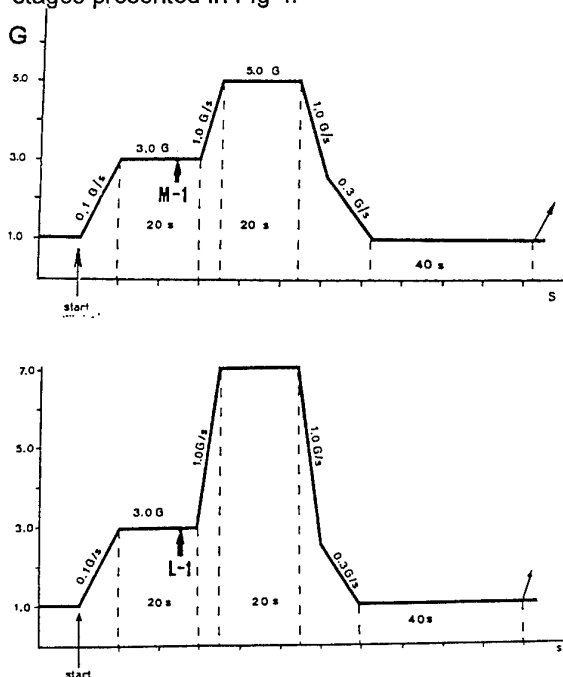
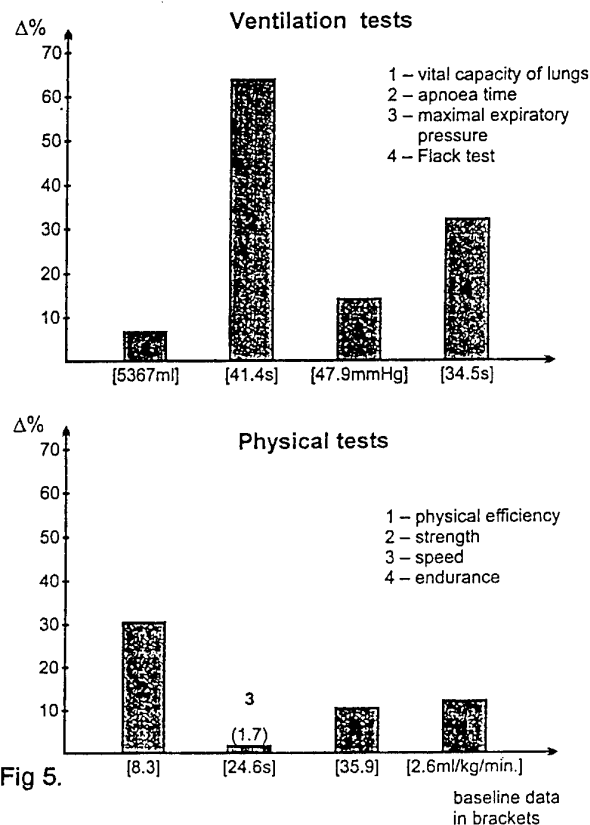


Fig.4 Acceleration characteristics applied in pilots during the centrifuge training.

Five seconds before start to the second level, the pilots perform L-1 or M-1 maneuver and repeat them on the maximum level of acceleration.

The physical training resulted in the increased tolerance of GOR by 1.3G and ROR by 1.5 G. The results showed increase of ATL after physical training. This training included elements of preparing the pilot's organisms for a rapid response and mobilizing compensatory reactions to acceleration influence.

Changes of ventilation and physical parameters after training



The training developed gravitational muscles and muscles groups affecting increased intra - abdominal and intra - thoracic pressure. It also adapted the organism to the tolerance of great blood volume and blood pressure changes in the head and pulmonary vascular system(during return).

Before and after the training ATL and physical parameters were determined represented by motoric characteristics of strength , endurance and speed. The ventilation parameters included: apnea time, maximal expiratory pressure and expiratory thrust time at 30 mmHg of force (Flack test) (Fig.5).

The results of these tests showed significant increase of respiratory parameters, determining physical conditions and the motoric characteristics of the subjects.

In our procedures we used an extensive physical pilots training programme, composing with gradually arising physical loads level, general gymnastics and recreation. We assumed, that the effective execution of L-1 or M-1 maneuvers is connected with tremendous physical effort and with marked fluctuations in blood pressure, intra-pulmonary and intra-abdominal pressure, which may lead to adverse training effects - if too intensive loads are used. The effectiveness of these training methods was confirmed during centrifuge tests with ROR and GOR acceleration (ATL increase was statistically significant).

Training the candidates / pilots with lowered ATL

If decreased ATL was found in the subjects examined in the centrifuge or in the subjects with in - flight consciousness loss episodes, it was necessary to apply another training method.

. In developing is method, attempts were made to apply +Gz stimuli with such characteristics which are the best tolerated by the organism (5).

For the evaluation of acceleration load intensity, pulsatile and mean blood flow velocity as heart rate were used. Slow acceleration onset rate was used (0.1G/s) and the subjects were exposed to such values of acceleration which did not exceed their physiological compensation limit. As the maximal +Gz load point , the moment of the appearance of diastolic retrograde blood flow velocity was accepted. It is presented in Fig.6

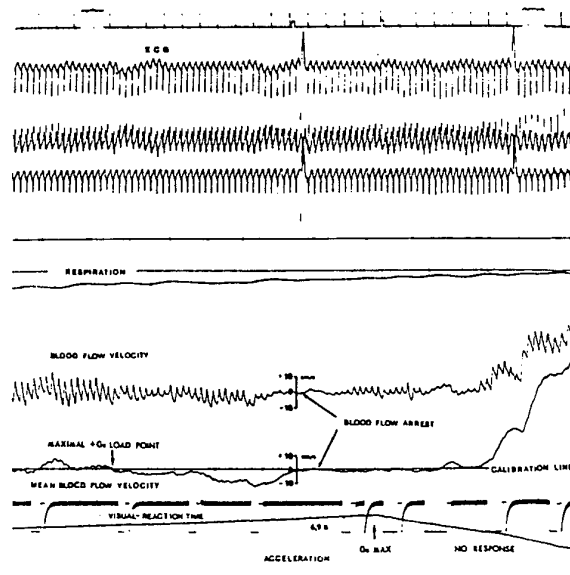


Fig 6

The centrifuging was stopped as soon as the mean blood flow velocity curve crossed the „zero calibration line“ and reach the negative values. The load value is changed after each centrifuge run, since the examination is stopped before the occurrence of retrograde blood flow from the head level . The time difference between the moment of braking of centrifuge and blood flow arrest in the temporal artery and the appearance of visual disturbances - is wide enough.

The margins of safety for the body systems loads applied in this training guaranteed that the centrifuge exposure would be stopped during the period of full circulatory performance. This is of particular importance, since each blackout is equivalent to a momentary breakdown of circulatory compensatory mechanisms, accompanied by a fall in the arterial blood pressure on the head level and lower body directed blood shifts.

Everyday centrifuge training was conducted during 3 weeks - four times a day.

The increase of ATL after the training is nearly 1.0 G. The obtained results show that HR is significantly modified during the initial phase of acceleration onset, during the maximal G load and after stopping the centrifuge.

It should be stressed, however, that the same men reached higher values of acceleration at the same or slightly higher HR values after the training. The comparison of the pre and post training mean blood velocity values indicates considerable differences during all the phases of centrifuge examination. The peak of this

index is noted at 2 G, both before and after the training, during ATL examination.

It is noticeable, that this index measured in the same men begins to drop in parallel +Gz increase. However is much slower after the training. The greatest difference is observed at 3 G, which suggests a significant influence of this phase upon obtaining higher values of ATL.

The presented centrifuge method is used in pilots after convalescence period or on finding lowered ATL produced by other causes (5).

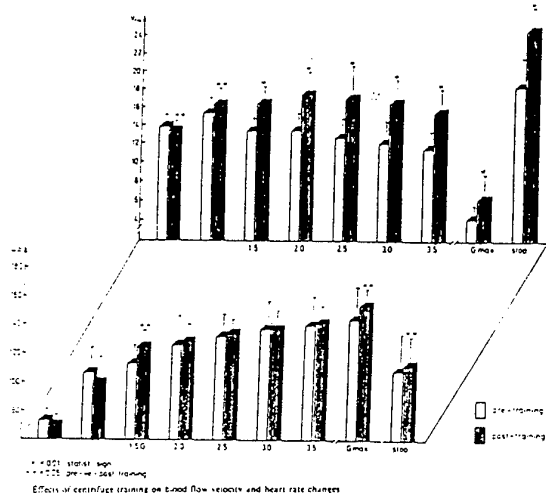


Fig.7

Conclusions

1. The selection program of the candidates preparing their conditions before first centrifuge examination is very effective and resulted in small screening.
2. The presented method of pilots' training to HPA including combination of respiratory exercises with isometric training developing anti gravitational muscles, improves effectiveness of L-1 and M-1 maneuvers and increases G - tolerance.
3. The human centrifuge training methods controlled by measurement of blood flow velocity and HR changes, can be used in pilots after a convalescence period or on finding lowered ATL produced by other causes.

References

1. Barański S., L. Markiewicz, M. Wojtkowiak, E. Sokołowski. The role of physical training in increasing +Gz acceleration tolerance in the initial phase of aviation training. The Physiologist, 1988, 31, 24-26
2. Kowalski W. Domaszuk J. Changes of acceleration tolerance during assisted PPB. Medycyna Lotnicza, 1976. nr. 50, 19-25

3. Marks J. Physical conditioning to improve acceleration tolerance in pilots. Postępy Astronautyki 1991, 23, 119-130
4. Wojtkowiak M. Assessment of tolerance limit in subjects tested on human centrifuge. Artificial satellites. 1976, vol. 11, 29-35
5. Wojtkowiak M. Effects of +Gz acceleration on human body systems as a form of training based on physiological data evaluation. Materia Medica Polona. 1990, Vol. 22, 311-16
6. Wojtkowiak M., Markiewicz L., Bartczak K. Possibilities of examining flying personnel in the modified human centrifuge. Medycyna Lotnicza 1993, 120-121, 53-62.
7. Wojtkowiak M. Selected physical training for cardiorespiratory manouvers increasing acceleration tolerance. Postępy astronautyki 1989, 22, 83-94.

Medical Monitoring of Centrifuge/PPB Subjects

Major Per-Gunnar Larsson, MD
Deputy Head of the Aeromedical Section
Swedish Armed Forces, Headquarters
S-107 85 Stockholm, Sweden

1. Short summary of activities in the field of Swedish human centrifuge

Since the beginning of the 50's there is a human centrifuge at the Karolinska Institutet in Stockholm. In course of time, this centrifuge has run out of date, and during the past few years no centrifuge activities have been conducted in Sweden.

However, considering our requirements for a human centrifuge for R&D, drafting, medical controls and training, the Stockholm centrifuge is at present being updated and will probably be in operation at the beginning of 1997. At the same time, a new Dynamic Flight Simulator (DFS) is being projected, which is going to be located in Linköping. Located there are also SAAB (manufacturer of the Gripen fighter), the Defence Material Administration's test centre (FMV:Prov) including the Aerophysiological laboratory and the Swedish Human Factor centre. A decision will probably be taken this summer and the operation can start in 1999. The advantages of locating the new centrifuge to Linköping is that there are many aviatric prospects there, which is favourable in view of R&D etc.

Since the beginning of the 80's, the fighter JAS 39 Gripen is being developed in Sweden, it is the fourth generation of fighters. This being a high performance plane with a load factor of +9 Gz, also a new flight combat suit has been developed since the middle of the 80's. The flight combat suit is a so called full coverage version with PPB, including a vest with chest bladder for counter pressure and integrated BC-protection. The centrifuge tests during the development of the flight combat suit have been made in the US (Brooks AFB, Texas). Test persons have been pilots flying the JAS 39 or pilots planning to fly the JAS 39. At the same time, the centrifuge tests have involved training for flying JAS 39. The approval requirements have been and are to withstand +7 Gz during GOR (0.1 Gz/s) in a G-suit without straining attempts and to withstand at least 30 s at 9 Gz with ROR (6 Gz/s). Apart from in the US, centrifuge training for JAS 39 flights has also been made in the Netherlands.

2. Current medical screening procedures for subjects for +Gz and PPB work during centrifuge tests/training

Our regular pilots also being our test subjects, they have undergone medical examinations, at first when

enroling for flight training, but also during the yearly medical health controls. Facing centrifuge training and tests, some of the examinations in the enrolment medical examination are added to the yearly health examination:

Enrolment (selection) medical health control:

- Clinical examination
- Lab tests: SR, Hb, Lipids, FBS, Fructoseamin, Uric acid, Creatinine, Albumin, Iron, total iron-binding capacity, Transferrin, AST, ALT, GGT, Alkaline phosphatase, Calcium, Urine analysis (glucose and protein)
- ENT examination including audiogram and mini pressure chamber for tubar function test
- Ophthalmologic examination including visual acuity, perimetry, colorvision, intraocular pressure, refraction and fundus examination (photo)
- Chest X-ray
- EEG
- Skinfold
- Spirometry (FVC, FEV_{1.0}, FEV% > 70%)
- Metacholine test
- Oxygen uptake test on cycle ergometer
- Onset of Blood Lactate Accumulation test (OBLA-test)
- Wingate test
- LBNP-test including psychometric tests
- Electrocardiographic exercise tests
- Resting ECG
- Echocardiogram/Doppler
- Anthropometry
- Strength tests (back strength, neck strength, arm strength, bench press, leg kicks)
- Dental assessments

Yearly health control

- Clinical examination
- Lab tests as above
- Visual acuity
- Audiogram
- Resting ECG
- Cooper test (3000 m running) or cycle ergometer (200 W for at least 6 min)
- Dental assessments

Health control preceeding centrifuge training/test

- Yearly health control as above plus the following examinations:
 - Electrocardiographic exercise tests
 - Echocardiogram/Doppler
 - Spirometry

- Anthropometry (for fitting the JAS 39 Gripen fighter)
- Strength tests
- Wingate test
- LBNP-test including psychometric tests

3. Description/case presentations of medical complications which have been observed in current or past subjects

This is a summary of the problems observed during development of the suit and centrifuge G-training over the past years in the US and in the Netherlands. In all, more than 50 pilots have been participating.

Comfort problems: Sore hips from the G-suit, musculoskeletal pain over the costal arch, chest pains, abdominal pains, pains in the buttocks which are not covered by the G-suit, heat load, fatigue.

Heart and circulation: Rhythm disturbances, pain in arms (a questionnaire on frequency, duration etc of arm pains is being evaluated, research in this area has been given priority and is done in cooperation with the Armstrong Laboratory in the US), pain in feet, inguinal pain, G-measles, haematoma incl. scrotal haematoma.

Neurology: Loss of sensibility (numbness) in arms and inguinal region, Grayout, G-LOC.

G-cough: Cough at/after 9 Gz.

Vertigo: When retarding the centrifuge, vertigo and nausea occurs, sometimes also vomiting.

Leak in oxygen mask: Leakage during PPB at 9 Gz, sometimes causing a flood of tears and a feeling of reduced G-tolerance.

BC-protection: Limitation of visual field.

Ability to speak: Difficulties at 9 Gz because of fear for G-LOC.

4. Plans on training of PTO and for drafting/training of pilots in centrifuge

At the prospect of starting the human centrifuge activity in Stockholm at Karolinska Institutet as of 1997, it has been planned to train a number of pilots to PTO's at Brooks AFB and Holloman AFB in late 1996. Also physicians, laboratory assistants and technicians will undergo training in the US to benefit from the experiences made there and in such a way secure the quality aspects of the centrifuge activity in Sweden.

It is anticipated to carry out more than 200 operations yearly in the centrifuge centre, including R&D, drafting, G-training and medical controls. It is foreseen to carry out G-training every third year for crews operating ejector seat planes.

A special programme for G-training is being prepared. Roughly, the following objectives and procedures are foreseen:

Objective: Knowledge of and training in the following areas

- Physiology incl. diet and fluid
- G-tolerance and its influences
- G-LOC and acceleration in high performance planes
- Training in L1 and M1 action
- Safety means, equipment and their function incl. handling
- G-training in human centrifuge

Centrifuge training:

- Demonstration run up to 4 Gz without pressurized G-suit (GOR)
- Setting of G-tolerance without counter action and without the G-suit functioning
- Training with activated G-suit and overpressure respiration up to 7 Gz (GOR) including respiratory training and M 1/L 1 action as well as muscle strain
- Training up to 9 Gz (1 Gz/s and 10 s at 9 Gz) with activated G-suit and PPB, with M 1/L 1 action and muscle strain
- Simulated air combat between 5 and 9 Gz with 10 s at each Gz-level. In all 10 periods with fast G-growth > 4 Gz/s
- It is important to train head movements at G-load to avoid illusions.
- Debriefing after training.

5. Medical controls including pilot equipment and equipment/layout of centrifuge gondola

- The pilot is connected to EKG for security reasons and to study possible extra systoles and arrhythmia at G-load.
- A sphygmomanometer (Finapress) provides information on how the counter actions of the pilot influence the blood pressure.
- An oxymeter provides information on how the blood is being oxygenated during G-load.
- The pilot is wearing his own equipment to make the centrifuge conditions resemble those of the airplane as close as possible.
- Video tapes and measured values are kept in records, an important matter for comparing the following centrifuge trainings.
- Cockpit, control columns, fastening belts, ventilation of suit and seat should be as close to the JAS 39 as possible to enable the pilot to transfer his centrifuge experiences to flying conditions.
- The peripheral vision is recorded via a light barrier.
- Vocal communication for giving instructions on e.g. respiratory techniques, counter actions and for issuing various tasks during G-training.

- - 0 - -

AGARD/AMP Workshop - Medical Monitoring of Centrifuge/PPB Subjects

N D C Green
Royal Air Force
School of Aviation Medicine
Farnborough, UK

RAF human centrifuge performance

The Royal Air Force human centrifuge was commissioned in 1954, and since then has been used principally in a research role. The centrifuge was originally specified to a maximum acceleration of +30 Gz; the machine is now limited to +9 Gz with a human subject on board, due to fatigue considerations. The maximum achievable onset rate is 1 G/s, and in this respect, the centrifuge performance is not representative of the fast jet flight environment. The interior of the gondola is extensively adaptable to enable the simple installation of different ejection seats, and items of life support equipment.

PBG utilisation

Initial centrifuge runs with PBG were performed during the early 1970's in association with studies concerning reclined seats; experimentation into the physiology of PBG began in earnest in 1988. In the last 8 years, over 5000 centrifuge runs using PBG have been performed at Farnborough, the great majority of which were made by members of the regular centrifuge subject panel. Over the period 1988-1996, the total number of subjects in this panel (and hence regularly exposed to PBG) was approximately 40.

A subset of centrifuge subjects also take part as subjects in flight trials in RAF SAM Hawk aircraft, which are fitted with PBG facilities and operate routinely up to +9 Gz. The Personal Equipment Connector used in

these aircraft is instrumented, so that inspiratory flow and mask tube pressure can be monitored.

Subject pool

Subjects are drawn from the staff of RAF SAM and are predominantly military. Subjects include both aircrew and non-aircrew, and may be male or female. Regular training sessions are held on all common centrifuge procedures, including use of the light bar to measure relaxed G tolerance, and the performance of the anti-G straining manoeuvre. The present panel consists of 8 regular members.

Screening procedures

Guidelines for medical screening are taken from RAF policy on regular fast jet passenger flying (1): all subjects exposed to greater than +4.5 Gz on a regular basis (i.e. greater than once every 4 months) require a yearly medical examination to Category 1 standard. Initial medical examination is performed at the RAF Central Medical Establishment, London, and subsequent annual medicals are performed at unit level by a station medical officer. No age limit is placed on centrifuge subjects, provided they fulfil the medical criteria.

Medical examination consists of:

- History
- Physical examination (including ophthalmology and audiometry)
- Urinalysis
- Peak expiratory flow
- Chest radiograph:
 - Initial
 - 5 yearly/as required
- Electrocardiograph (ECG):
 - 5 yearly up to age 30
 - 2 yearly age 30 - 40
 - increasing in frequency above this age

At present there is no requirement for a blood test, echocardiography, exercise testing, 24 hour ECG, cervical spine X-ray or computed tomography/magnetic resonance imaging.

During centrifuge exposures, subjects are monitored on closed circuit television, and by single channel ECG. No specific run termination criteria for ECG changes exist, and aircrew undergoing high G training may elect not to be monitored if they so wish. To enable prompt treatment of a subject in the gondola in the case of an emergency, a medical officer sits at the centre of rotation of the centrifuge arm at a monitoring station during runs.

Incidents

No serious incidents have been reported either during or after centrifuge sessions involving PBG. Cardiac dysrhythmias, such as ventricular ectopy and short runs of ventricular tachycardia, have occasionally been observed in subjects during acceleration exposures, but these have not resulted in the termination of centrifuge runs.

Anecdotal evidence suggests the incidence of frontal and/or maxillary sinusitis may be increased in those frequently exposed to PBG on the centrifuge. Furthermore, those individuals with symptoms of mild upper respiratory tract infection who are exposed to PBG may be more likely to progress to chest infection or sinusitis. Although aircrew do not generally fly with upper respiratory tract infections, mild or sub-clinical cases may be exacerbated by the use of PBG, and this could have operational significance.

Florid petechiae and forearm pain have long been associated with high +Gz exposure and PBG on the centrifuge, when the arms are in a dependent position and arm pain is also

present during exposure to PBG in the RAF SAM Hawk aircraft. Current evidence suggests that the origin of this pain is probably vascular, and most likely to originate in the large, superficial veins of the forearm. Venous pressures of over 200 mmHg have been recorded in the forearm in flight, with a pressure breathing level of 60 mmHg at +9 Gz, with hands on Hawk stick and throttle (2). By way of contrast, the normal forearm venous pressure at +1 Gz when seated in this position is approximately 40 mmHg. It seems likely that the pain occurs when veins or venules are stretched beyond their elastic limit. The long term consequences of exposure to such venous pressures are unknown; having experienced arm pain in-flight or on the centrifuge, subjects often report residual pain for up to 3 days. There is no evidence of any long term vascular change in the small pool of subjects who have regularly experienced arm pain, but no histological investigation of these subjects' forearm vasculature has been carried out.

Investigation of lung function during PBG, using different areas of chest counter-pressure coverage, has so far revealed little evidence of lung over-distension. The ratio of expiratory reserve volume (ERV) to vital capacity (VC) (used as an index of lung over-distension) was measured in 5 high G experienced subjects, and found not to increase at +9 Gz while pressure breathing at 65 mmHg (3). Investigation of this aspect is incomplete, as residual lung volume and regional (and especially apical) alveolar volumes must be determined before accurate assessment of the risk of lung over-distension can be made.

References

1. D/Health Policy Letter 8/92 (JS) dated 23 Jul 92, Ministry of Defence, London.
2. Lewis M T, Green N D C, Adcock T R, Peterson M K and Prior A R J. In-flight assessment of arm pain at high +Gz. RAF SAM Report 02/95 (September 1995), Ministry of Defence, London.
3. Green, N D C. Lung volume changes under positive pressure breathing for +Gz protection. Royal Air Force School of Aviation Medicine Report 01/95 (July 1995), Ministry of Defence, London.

© British Crown Copyright 1996/MOD

Published with the permission of the controller of Her Britannic Majesty's Stationary Office.

AGARD AEROSPACE MEDICAL PANEL WORKSHOP

USAF BRIEFING TO THE WORKSHOP (synopsis by Workshop Director)

The USAF representatives at the Workshop included Colonel Gary Saboe, Colonel Doug Ivan and Mr. John Patterson. Colonel Saboe reported that the Armstrong Laboratory at Brooks has a pool of approximately 20 subjects who currently participate in G-protocols up to +9Gz. The medical screening for these subjects has been previously published (1) and includes:

- a Flying Class III medical examination
- an echocardiogram
- a resting ECG
- blood and urine screening
- chest x-ray
- spinal x-rays
- pregnancy tests for females before each new protocol

The G research envelope at the Armstrong Laboratory is being expanded from 9 to +12Gz and subjects in this extended research protocol undergo more intensive medical screening. This screening includes (but is not limited to)

- MRIs of the head and axial spine. Colonel Saboe reported that the initial experience with these MRIs is that there is considerable inter- and even intra-observer variability and the clinical relevance of MRI findings is not clear.

- detailed ophthalmologic evaluation (briefed by Colonel Doug Ivan)
 - visual fields
 - corneal topography
 - electroretinograms
 - visual evoked potentials
 - contrast sensitivity
- detailed vestibular examination
 - audiometry
 - VORs
 - oculokinetic reflex

- detailed neuropsychiatric assessment (briefed by Mr. John Patterson) designed to assess baseline personality, global cognitive function, attention, concentration, working and verbal memory, visuo-spatial processing, vigilance, reaction times, and mental processing speeds. The tools used include:

- Microcog
- digit symbol symbol span
- Trails B
- Benton Supraspan
- Judgement of line orientation
- Grooved pegboard
- multidimensional aptitude battery

Medical Screening and Complications in Subjects for Acceleration and Positive Pressure Breathing Research

Commander David G. McGowan, MD, MPH
United States Naval Air Warfare Center
Warminster, Pennsylvania

1. Hazardous duty subject eligibility and qualification

- 1.1. must have supervisory permission, and be either:
 - 1.1.1. active duty military
 - 1.1.1.1. compensation is \$110 per month whenever any hazardous duty exposure occurs regardless of duration of exposure
 - 1.1.1.2. injury and potential disability covered by military medical system
 - 1.1.2. Department of Defense employee
 - 1.1.2.1. compensation is 125% of normal daily wage
 - 1.1.2.2. injury and potential disability covered by Federal Workman's Compensation program
- 1.2. basically want them as similar as possible to aviation population
 - 1.2.1. height, weight, age, etc., limitations as for flight status
 - 1.2.1.1. though standards for visual acuity, etc., are less strict
 - 1.2.2. no significant past or current disease or disability
 - 1.2.3. no chronic medications
 - 1.2.4. no past history of seizures, heat or exercise intolerance, significant motion sickness, claustrophobia, personality disorder, or recurrent neck or back problems
 - 1.2.5. women may not:
 - 1.2.5.1. be pregnant
 - 1.2.5.2. have breast implants
- 1.3. subject is interviewed and completes a familiarization exposure before beginning initial physical process
 - 1.3.1. fam ride is +3Gz max, four runs total
 - 1.3.2. confirms subject interest and allows us to evaluate them

2. Initial hazardous duty physical

- 2.1. done once only upon initial application
- 2.2. modeled after aviation physical standards for the non-pilot
- 2.3. history and physical exam done with medical monitor physician
- 2.4. laboratory
 - 2.4.1. complete blood count, urinalysis
 - 2.4.2. chest X-ray
 - 2.4.3. tuberculosis skin test (PPD)
 - 2.4.4. screen for hepatitis A,B, and C, syphilis, and HIV
 - 2.4.5. cholesterol (total, HDL) and triglyceride
 - 2.4.6. resting 12-lead electrocardiogram
- 2.5. ancillary studies
 - 2.5.1. distant and near visual acuity
 - 2.5.1.1. glasses or contacts ok, but total myopic correction must be less than -5.75 diopters
 - 2.5.2. intraocular pressure
 - 2.5.3. color vision
 - 2.5.4. dental exam
 - 2.5.5. pulmonary function test
 - 2.5.6. audiogram
 - 2.5.7. exercise stress test (treadmill)
 - 2.5.7.1. must complete to 100% predicted safe pulse
 - 2.5.8. cardiac echo with doppler flows
 - 2.5.9. total spinal X-rays (PA, lateral, and oblique cervical, thoracic and lumbar spine; sacro-iliac joints; pelvis; and odontoid view)
 - 2.5.10. 24-hour holter monitor EKG recording if history of palpitations
- 2.6. during initial examination, we have disqualified
 - 2.6.1. four subjects for schmorl's nodes
 - 2.6.2. two subjects for spondylololsthesis
 - 2.6.3. one subject for dysrhythmias during treadmill

2.7 because of the fact that most subjects are disqualified because of spinal X-ray findings, cost effectiveness would suggest that spinal films be done; however, due to the potential risk of the radiation exposure, we have elected to ensure that the subject is otherwise fully qualified before obtaining the spinal films

3. annual re-examination

- 3.1. history and physical exam done with medical monitor physician
 - 3.1.1. laboratory - same as initial
 - 3.1.2. ancillary studies - same as initial, except do not repeat treadmill, echo, or spinal films
 - 3.1.3. we have had no unexpected findings on annual re-exams
 - 3.1.4. we have dropped the qualifications on three subjects because of personality related issues

4. termination or exit examination

- 4.1 currently do not perform as have no way to tell when a subject is leaving

5. record keeping

- 5.1. all records (physicals, test results, individual exposure sheets, etc.) accumulated in a subject's personal folder, which are held by the facility indefinitely
- 5.2. spinal films are obtained and held on site for easy access

6. pregnancy testing

- 6.1. perform over-the-counter urine HCG testing on each day before exposure
- 6.2. if HCG positive, they are disqualified from continued hazardous duty exposure until HCG becomes negative
- 6.3. we record, but do not adjust exposure for menstrual period

7. exposures over +10Gz. We have no standard policy

- 7.1. each project is required to establish an individualized policy as to selection, screening, monitoring, and follow-up testing
- 7.2. this then is part of protocol, and requires both Human Use Committee and Command approval

8. recent injuries/interesting occurrences

- 8.1. our work done over last 18 months has been with experienced male subjects, except for the "small female" strength and endurance study. We had no occurrences with the males

8.2. PVCs - two females

8.2.1. reliably demonstrated between 4 and 20 uniform PVCs per minute without coupling, and with no more than 1:3 ratio; unrelated to G level, profile, or work-load. Subjects were unaware of them, and they did not occur outside the centrifuge. Possibly adrenaline related (though resting pulse in the centrifuge was 80-100, which is common for us).

8.3. Gz related PVCs - two (other) females

8.3.1. benign, uniform PVCs predictably appear when the subject goes above +5Gz; disappear below +5Gz. Unrelated to profile, work load, anti-G straining maneuver or centrifuge experience level; possibly related to stretch of the myocardium??

8.3.2. dysrhythmias are normally uncommon at Warminster (perhaps 1 in 10 demonstrated any dysrhythmia before the female study). We only have six female subjects, all below 55 kg, and PVCs have occurred in four; all have a normal cardiac echo and treadmill exams, and none show significant PVCs outside of the centrifuge

8.4. popliteal fossa hematoma

- 8.4.1. occurred in small stature female subject (152cm, 52 kg)
- 8.4.2. popliteal cut-out of anti-G suit was found to be over her upper calf
- 8.4.3. no subsequent problem with properly fitting anti-G suit

8.5 calf muscle pull

- 8.5.1. in an inexperienced subject who was "standing on the rudder pedals" during the anti-G straining maneuver

CONSENSUS AGARD PROTOCOL **for the** **MEDICAL SCREENING OF SUBJECTS** **FOR ACCELERATION AND POSITIVE PRESSURE BREATHING** **RESEARCH**

THE AGARD/AMP WORKSHOP PANEL

INTRODUCTION

One of the Objectives of the AMP Workshop was to construct a consensus protocol of medical screening procedures for selection and periodic screening of subjects for research in acceleration and positive pressure breathing.

Each NATO acceleration research facility has its own procedures for medical screening, but the only published procedure is the USAFSAM protocol outlined by Whinnery and Gillingham (1). This was published in 1983, and was appropriate at that time, but because of the significant changes in G-profiles, onset rates and peak G-exposures on NATO centrifuges as well as improvements in non-invasive medical technology, publication of a revised and current protocol was considered an important objective.

This was an ambitious undertaking considering the time constraints of the Workshop and the international panel of representatives. However, with the co-operation of Workshop members, the objective was completed and this protocol constructed which represents the consensus opinion of the Workshop members. It was first created as a draft protocol at the Workshop and subsequently circulated to all Workshop members for review. These review comments have been incorporated into this final revision.

The Protocol was derived by a consensus opinion of Workshop members. It represents a recommended set of

Guidelines, and not a regulation or standard. The recommendations are based not only on current medical and scientific knowledge but also medical concerns not necessarily supported by data at this point. It is anticipated that this Protocol will be reviewed and updated as more experienced is gained and more data becomes available.

The Workshop set out to identify two types of screening

- a. Essential. Minimum medical screening considered acceptable for subjects of acceleration research.
- b. Optional. Additional optional procedures which may be included to provide optimal screening.

The resultant protocol is given in Table 1.

GENERAL PRINCIPLES

Aim of Medical Surveillance. The recommended screening procedures are designed to protect subjects' health and are not intended primarily for medical research, although the data collected may be used without individual subject identification in a collective fashion to report clinical findings.

Risk/Benefits Subjects who volunteer for research protocols involving exposure to acceleration or positive pressure breathing incur no personal benefit and so from a medico-ethical viewpoint, the risks of such exposure must be considered to exceed that of normal daily living.

Aircrew personnel undergoing acceleration/PPB exposure for training purposes constitute a different population in which some benefit may be incurred; medical screening of this population is not addressed in this document.

Levels of Risk

Based on current knowledge and experience, exposures up to +7 Gz are considered to constitute a slightly increased risk for healthy subjects. Exposure beyond +7Gz for greater than 15 seconds is defined as High Sustained G. This level of exposure, and unassisted positive pressure breathing to 30mm Hg or assisted pressure breathing to 70mmHg entail moderate increased risk to subjects about which much is known, while exposures beyond +9Gz for 15 seconds or more extreme PPB levels (>70mmHg/APPB) represent substantially increased risks about which little is known. Our recommendations for medical screening are stratified based on this subdivision of risk assessment.

Experimental protocols investigating frontier (superagility) realms of acceleration research - such as those involving extremes of axes other than +Gz, extensively sustained (>60sec) plateaus, very rapid onset rates (>10G/sec), or negative/positive transitions - represent areas about which little is known and therefore involve unforeseen risks. Accordingly, such protocols should provide for more aggressive subject medical surveillance as recommended for >9Gz protocols.

Subject age (>40) is an independent risk factor and medical screening procedures should be adjusted to account for this.

Female Subjects. Unanimous concern was expressed about the unknown effects of acceleration/PPB on a developing fetus, and so all agreed that such protocols should make all reasonable efforts to ensure that female subjects are aware of these concerns and are not pregnant when participating in experiments.

Experienced Aircrew as Subjects. Much discussion also took place surrounding the issue of whether aircrew with extensive exposure to the physiologically stressful environments of high-performance aircraft could be considered to be a separate sub-population in acceleration /PPB research who could be deemed to require less stringent medical screening. It was the consensus that if participating as volunteer subjects in research protocols, medical screening should be the same for aircrew as for other subjects. Aircrew involved in protocols designed to test and evaluate equipment within the acceleration/positive pressure envelopes that they may experience in operational flying may be considered to be exposed to risks no greater than in their normal occupation and for such protocols additional medical screening may not be required.

References:

1. Whinnery JE, Gillingham KK. Medical standards for experimental human use in acceleration stress research. *Aviat. Space Environ. Med.* 1983; 54; 241-245.

Table 1: Consensus Screening Protocol

Peak +Gz level of experimental protocol:		Initial		Periodic	
		≤9	>9	≤9	>9
Clinical Examination		E	E	E(1)	E(1)
Audiogram		E	E	E(1)	E(1)
Resting ECG		E	E	E(1)	E(1)
Lab	Complete Blood Count (CBC) - *	E	E	E(1)	E(1)
	INR/PTT	E	E	O	O
	Urea, Creatinine	E	E	E(1)	E(1)
	AST/ALT/GGT (liver enzyme assays)	E	E	E(1)	E(1)
	Sensitive TSH Test (sTSH)	E	E	O	O
HIV/Hepatitis A/B/C Serology/Serologic Test for Syphilis (STS)		E	E	E	E
	Fasting Blood Sugar (FBS)	E	E	E	E
	Lipids	E	E	O	O
	Electrolytes	O	O	O	O
	Tuberculosis (TST) Testing	O	O	O	O
	Urinalysis	E	E	E	E
Ophthalmologic Assessment, including: visual acuity, fields (by perimetry), colour vision (incl blue-yellow testing), cycloplegic refraction, dilated fundus examination, intraocular pressures		E	E	O	E
Dental Assessment		O	O	O	O
X-Ray	CXR (PA view; others optional)	E	E	O(5)	O
	Spine (PA + lat views)	E	E	O(5)	-
MRI	head + saggital spinal cord	O	E	O	E(x)
	MRA head	O	E	O	E(x)
Maximum treadmill exercise test (for arrhythmias)		E	E	O	O
Echocardiogram/Doppler		E	E	E	E
Electroencephalogram		O	E	O	O
Holter Monitor		O	O	O	O
Neuropsych Testing§		E	E	E	E
Pulmonary Function Tests‡		E	E	E	E
High Resolution Computed Tomography (HRCT) Scan Chest		O	E	O	E(x)
Special Vision Tests¶			E		E
Special Audiometric Tests¶			E		E

Abbreviations:E - These studies are considered to be an essential element of medical surveillanceO - These studies are a recommended but optional element of medical surveillance(X) - refers to study performed on exit from active participation in G/PPB experiments

(1) - performed at yearly intervals (5) - performed at five-year intervals

Notes:

* - Other hematologic tests that should be considered (depending on prevalence in national populations) include tests for Sickle Cell Trait and Disease and G6PD deficiency

§ - Some objective assessment of subjects' cognitive function. The detail and rigour of such testing is left to individual nations' discretion.

‡ - Pulmonary function tests should include as a minimum, assessment of expiratory flow rates, lung volumes, and diffusing capacity. Airway reactivity may be assessed in individual cases by methacholine challenge.

¶ - this testing should be determined by their availability and reliability in each nation. Some considerations: ride-to-ride surveillance using quick vision/phoria/stereopsis testers (eg, US "Armed Forces Vision Tester" and "TITMIS"); visual evoked potentials; contrast sensitivity; fundus photography.

PROTOCOL FOR REPORTING MEDICAL OCCURRENCES
IN NATO CENTRIFUGE SUBJECTS

One of the objectives of the Workshop was to create a database for reporting medical occurrences in centrifuge or PPB subjects related to, or potentially related to exposure to acceleration or positive pressure breathing. This collative data will be reported to the members of the Workshop on an annual basis, and may be reported in the aerospace medical literature after discussion with members of the Workshop.

The object of the database is not to raise alarm about medical occurrences, but to maintain awareness of NATO medical officers responsible for the health and safety of such subjects of potential medical concerns.

The database will be maintained by the Acceleration Medical Officer at the Defence and Civil Institute of Environmental Medicine in Toronto, Canada.

Using the format on the following page, Workshop members or their delegates are requested to forward occurrences to:

Acceleration Medical Officer
Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West
North York, Ontario
CANADA
M3M 3B9

MEDICAL OCCURENCE IN NATO ACCELERATION/PPB SUBJECT**NATURE OF OCCURENCE:**

(Narrative description of incident)

DATE:**FACILITY/COUNTRY:****G-PROFILE:****PPB:****AGE OF SUBJECT:****GENDER:****PREVIOUS EXPOSURE TO G/PPB**

(Quantitative if possible)

RESULTS OF INVESTIGATIONS:**ADMINISTRATIVE DISPOSITION:**

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's Reference AGARD-AR-352	3. Further Reference ISBN 92-836-0045-2	4. Security Classification of Document UNCLASSIFIED/ UNLIMITED														
5. Originator Advisory Group for Aerospace Research and Development North Atlantic Treaty Organization 7 rue Ancelle, 92200 Neuilly-sur-Seine, France																	
6. Title Medical Screening of Subjects for Acceleration and Positive Pressure Breathing																	
7. Presented at/sponsored by Aerospace Medical Panel																	
8. Author(s)/Editor(s) Multiple			9. Date July 1997														
10. Author's/Editor's Address Multiple			11. Pages 48														
12. Distribution Statement There are no restrictions on the distribution of this document. Information about the availability of this and other AGARD unclassified publications is given on the back cover.																	
13. Keywords/Descriptors <table border="0"><tr><td>Medical examination</td><td>Experimentation</td></tr><tr><td>Aerospace medicine</td><td>Gravity reduction</td></tr><tr><td>Pressure breathing</td><td>Research projects</td></tr><tr><td>Stress (physiology)</td><td>Centrifuges</td></tr><tr><td>Acceleration stresses</td><td>Occupational diseases</td></tr><tr><td>Acceleration tolerance</td><td>Flight crews</td></tr><tr><td>NATO forces</td><td></td></tr></table>				Medical examination	Experimentation	Aerospace medicine	Gravity reduction	Pressure breathing	Research projects	Stress (physiology)	Centrifuges	Acceleration stresses	Occupational diseases	Acceleration tolerance	Flight crews	NATO forces	
Medical examination	Experimentation																
Aerospace medicine	Gravity reduction																
Pressure breathing	Research projects																
Stress (physiology)	Centrifuges																
Acceleration stresses	Occupational diseases																
Acceleration tolerance	Flight crews																
NATO forces																	
14. Abstract <p>The AGARD Aerospace Medical Panel sponsored a Workshop on the Medical Surveillance of Subjects for Acceleration Research. There remain unanswered questions about the possible long-term medical complications of repetitive exposure to G forces. The concept underlying the Workshop was that subjects for acceleration research form a highly medically screened cohort in whom medical concerns about G exposure might be addressed by pooling data. Workshop participants from Canada, France, Germany, Japan, the Netherlands, Poland, Sweden, the UK, and the US Navy and USAF, presented the current procedures in place for the medical screening of acceleration subjects. The outcomes of the Workshop included a consensus protocol for medical screening of subjects for acceleration research, and a protocol for a database to track medical occurrences of NATO centrifuges.</p>																	

AGARDNATO  OTAN

7 RUE ANCELLE • 92200 NEUILLY-SUR-SEINE

FRANCE

Télécopie 0(1)55.61.22.99 • Téléc 610 176

DIFFUSION DES PUBLICATIONS**AGARD NON CLASSIFIEES**

L'AGARD détient un stock limité de certaines de ses publications récentes. Celles-ci pourront éventuellement être obtenus sous forme de copie papier. Pour de plus amples renseignements concernant l'achat de ces ouvrages, adressez-vous à l'AGARD par lettre ou par télécopie à l'adresse indiquée ci-dessus. *Veuillez ne pas téléphoner.*

Des exemplaires supplémentaires peuvent parfois être obtenus auprès des centres de diffusion nationaux indiqués ci-dessous. Si vous souhaitez recevoir toutes les publications de l'AGARD, ou simplement celles qui concernent certains Panels, vous pouvez demander d'être inclus sur la liste d'envoi de l'un de ces centres.

Les publications de l'AGARD sont en vente auprès des agences de vente indiquées ci-dessous, sous forme de photocopie ou de microfiche. Certains originaux peuvent également être obtenus auprès de CASI.

CENTRES DE DIFFUSION NATIONAUX**ALLEMAGNE**

Fachinformationszentrum Karlsruhe
D-76344 Eggenstein-Leopoldshafen 2

BELGIQUE

Coordonnateur AGARD-VSL
Etat-major de la Force aérienne
Quartier Reine Elisabeth
Rue d'Evere, 1140 Bruxelles

CANADA

Directeur - Gestion de l'information
(Recherche et développement) - DRDGI 3
Ministère de la Défense nationale
Ottawa, Ontario K1A 0K2

DANEMARK

Danish Defence Research Establishment
Ryvangs Allé 1
P.O. Box 2715
DK-2100 Copenhagen Ø

ESPAGNE

INTA (AGARD Publications)
Carretera de Torrejón a Ajalvir, Pk.4
28850 Torrejón de Ardoz - Madrid

ETATS-UNIS

NASA Center for AeroSpace Information (CASI)
800 Elkridge Landing Road
Linthicum Heights, MD 21090-2934

FRANCE

O.N.E.R.A. (Direction)
29, Avenue de la Division Leclerc
92322 Châtillon Cedex

GRECE

Hellenic Air Force
Air War College
Scientific and Technical Library
Dekelia Air Force Base
Dekelia, Athens TGA 1010

ISLANDE

Director of Aviation
c/o Flugrad
Reykjavik

ITALIE

Aeronautica Militare
Ufficio del Delegato Nazionale all'AGARD
Aeroporto Pratica di Mare
00040 Pomezia (Roma)

LUXEMBOURG

Voir Belgique

NORVEGE

Norwegian Defence Research Establishment
Attn: Biblioteket
P.O. Box 25
N-2007 Kjeller

PAYS-BAS

Netherlands Delegation to AGARD
National Aerospace Laboratory NLR
P.O. Box 90502
1006 BM Amsterdam

PORTUGAL

Estado Maior da Força Aérea
SDFA - Centro de Documentação
Alfragide
2700 Amadora

ROYAUME-UNI

Defence Research Information Centre
Kentigern House
65 Brown Street
Glasgow G2 8EX

TURQUIE

Millî Savunma Başkanlığı (MSB)
ARGE Dairesi Başkanlığı (MSB)
06650 Bakanlıklar-Ankara

AGENCES DE VENTE**NASA Center for AeroSpace Information (CASI)**

800 Elkridge Landing Road
Linthicum Heights, MD 21090-2934
Etats-Unis

The British Library Document Supply Division

Boston Spa, Wetherby
West Yorkshire LS23 7BQ
Royaume-Uni

Les demandes de microfiches ou de photocopies de documents AGARD (y compris les demandes faites auprès du CASI) doivent comporter la dénomination AGARD, ainsi que le numéro de série d'AGARD (par exemple AGARD-AG-315). Des informations analogues, telles que le titre et la date de publication sont souhaitables. Veuillez noter qu'il y a lieu de spécifier AGARD-R-nnn et AGARD-AR-nnn lors de la commande des rapports AGARD et des rapports consultatifs AGARD respectivement. Des références bibliographiques complètes ainsi que des résumés des publications AGARD figurent dans les journaux suivants:

Scientific and Technical Aerospace Reports (STAR)

STAR peut être consulté en ligne au localisateur de ressources uniformes (URL) suivant:
<http://www.sti.nasa.gov/Pubs/star/Star.html>
STAR est édité par CASI dans le cadre du programme NASA d'information scientifique et technique (STI)
STI Program Office, MS 157A
NASA Langley Research Center
Hampton, Virginia 23681-0001
Etats-Unis

Government Reports Announcements & Index (GRA&I)

publié par le National Technical Information Service
Springfield
Virginia 2216
Etats-Unis
(accessible également en mode interactif dans la base de données bibliographiques en ligne du NTIS, et sur CD-ROM)



Imprimé par le Groupe Communication Canada Inc.

(membre de la Corporation St-Joseph)

45, boul. Sacré-Cœur, Hull (Québec), Canada K1A 0S7

AGARD holds limited quantities of some of its recent publications, and these may be available for purchase in hard copy form. For more information, write or send a telefax to the address given above. *Please do not telephone.*

Further copies are sometimes available from the National Distribution Centres listed below. If you wish to receive all AGARD publications, or just those relating to one or more specific AGARD Panels, they may be willing to include you (or your organisation) in their distribution.

AGARD publications may be purchased from the Sales Agencies listed below, in photocopy or microfiche form. Original copies of some publications may be available from CASI.

NATIONAL DISTRIBUTION CENTRES

BELGIUM

Coordonnateur AGARD — VSL
Etat-major de la Force aérienne
Quartier Reine Elisabeth
Rue d'Evere, 1140 Bruxelles

CANADA

Director Research & Development
Information Management - DRDIM 3
Dept of National Defence
Ottawa, Ontario K1A 0K2

DENMARK

Danish Defence Research Establishment
Ryvangs Allé 1
P.O. Box 2715
DK-2100 Copenhagen Ø

FRANCE

O.N.E.R.A. (Direction)
29 Avenue de la Division Leclerc
92322 Châtillon Cedex

GERMANY

Fachinformationszentrum Karlsruhe
D-76344 Eggenstein-Leopoldshafen 2

GREECE

Hellenic Air Force
Air War College
Scientific and Technical Library
Dekelia Air Force Base
Dekelia, Athens TGA 1010

ICELAND

Director of Aviation
c/o Flugrad
Reykjavik

ITALY

Aeronautica Militare
Ufficio del Delegato Nazionale all'AGARD
Aeroporto Pratica di Mare
00040 Pomezia (Roma)

LUXEMBOURG

See Belgium

NETHERLANDS

Netherlands Delegation to AGARD
National Aerospace Laboratory, NLR
P.O. Box 90502
1006 BM Amsterdam

NORWAY

Norwegian Defence Research Establishment
Attn: Biblioteket
P.O. Box 25
N-2007 Kjeller

PORTUGAL

Estado Maior da Força Aérea
SDFA - Centro de Documentação
Alfragide
2700 Amadora

SPAIN

INTA (AGARD Publications)
Carretera de Torrejón a Ajalvir, Pk.4
28850 Torrejón de Ardoz - Madrid

TURKEY

Millî Savunma Başkanlığı (MSB)
ARGE Dairesi Başkanlığı (MSB)
06650 Bakanlıklar-Ankara

UNITED KINGDOM

Defence Research Information Centre
Kentigern House
65 Brown Street
Glasgow G2 8EX

UNITED STATES

NASA Center for Aerospace Information (CASI)
800 Elkridge Landing Road
Linthicum Heights, MD 21090-2934

SALES AGENCIES

NASA Center for Aerospace Information (CASI)

800 Elkridge Landing Road
Linthicum Heights, MD 21090-2934
United States

The British Library Document Supply Centre

Boston Spa, Wetherby
West Yorkshire LS23 7BQ
United Kingdom

Requests for microfiches or photocopies of AGARD documents (including requests to CASI) should include the word 'AGARD' and the AGARD serial number (for example AGARD-AG-315). Collateral information such as title and publication date is desirable. Note that AGARD Reports and Advisory Reports should be specified as AGARD-R-nnn and AGARD-AR-nnn, respectively. Full bibliographical references and abstracts of AGARD publications are given in the following journals:

Scientific and Technical Aerospace Reports (STAR)

STAR is available on-line at the following uniform resource locator:

<http://www.sti.nasa.gov/Pubs/star/Star.html>

STAR is published by CASI for the NASA Scientific and Technical Information (STI) Program

STI Program Office, MS 157A
NASA Langley Research Center
Hampton, Virginia 23681-0001
United States

Government Reports Announcements & Index (GRA&I)

published by the National Technical Information Service
Springfield

Virginia 22161

United States

(also available online in the NTIS Bibliographic Database or on CD-ROM)



Printed by Canada Communication Group Inc.

(A St. Joseph Corporation Company)

45 Sacré-Cœur Blvd., Hull (Québec), Canada K1A 0S7